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Are interventions for low-income groups effective in changing healthy eating, physical activity and smoking behaviours? A systematic review and meta-analysis

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Abstract

Background: Individuals can positively impact health and longevity by changing health-related behaviours, including diet, smoking and physical activity. Health outcomes and behaviours are unevenly distributed: people with lower socio-economic status, such as those with a low income, are less likely to engage in positive health behaviours and experience good health. No systematic review with meta-analysis has examined randomised controlled trial (RCT) evidence of the effectiveness of behaviour change interventions for low-income groups.

Objective: Examine RCTs and Cluster RCTs of behavioural interventions targeting diet, physical activity or smoking in low-income adults.

Design: Systematic review with random effects meta-analyses. Studies before 2006 were identified from a previously published systematic review (searching 1995-2006) with similar but broader inclusion criteria (including non-randomised controlled trials). Studies from 2006 onwards were identified from eight electronic databases using a similar search strategy.

Data sources: Medline, Embase, PsycINFO, ASSIA, CINAHL, Cochrane Controlled Trials, Cochrane Systematic Review and DARE Electronic Databases.

Eligibility criteria for selecting studies: RCTs published since 1995; interventions targeting dietary, physical activity and smoking behaviours; low-income adults; reporting of behavioural outcomes.

Main outcome measures: Dietary, physical activity and smoking cessation behaviours.

Results: 32 studies containing 42 interventions with 16,012 participants met inclusion criteria. The post-intervention standardised mean difference (SMD) between intervention and control groups was 0.19 [95%CI 0.13 to 0.24] for diet, 0.18 [95%CI 0.02 to 0.33] for physical activity and a relative risk

(RR) of 1.63 [95%CI 1.37 to 1.95] for smoking. Studies reporting follow-up results suggested that effects were maintained for diet [SMD 0.16, 95%CI 0.08 to 0.25] but not physical activity [SMD 0.17, 95%CI -0.02 to 0.37] or smoking [RR 1.07, 95%CI 0.9 to 1.29].

Conclusions: Behaviour change interventions for low-income groups had small positive effects on behaviour. Further work is required to improve the effectiveness of behaviour change support for deprived populations.

Article Summary

Strengths and limitations of the study

- This was a comprehensive systematic review with meta-analysis to examine the effects of behavioural interventions in a deprived proportion of the population, namely 'low-income groups'
- We updated a previous review on this topic and focussed exclusively on evidence from RCTs, which are often termed 'the golden standard' of research.
- Applying meta-analysis enabled us to summarise the data quantitatively and estimate pooled effect sizes, which could be compared to those for interventions from other population groups.
- We searched for studies using a range of databases, but we may have missed relevant studies not indexed within the 'grey literature'.
- The majority of the studies were conducted in the USA, potentially limiting generalisability and did not tend to describe their intervention content comprehensively, making it difficult to further explore 'what works' for low-income groups.

Introduction

Health outcomes are strongly correlated with social position in societies across the western world: individuals from deprived backgrounds die younger and experience a greater proportion of their lives with a disability.[1-5] In the most deprived areas of England, for example, life expectancy is approximately eight years less, and disability-free life expectancy 15 years less than in the least deprived areas.[1] Amongst several deprivation indicators, a person's individual or household income is widely recognised as being strongly positively correlated with health outcomes[3]. The social gradient in health is predicted to steepen further[2] despite policy efforts aimed at maximising equality.[3-5]

Behaviours linked to health, particularly healthy eating, physical activity and smoking, show a similar social gradient to health outcomes. Consumption of tobacco, a poor diet and a lack of physical activity are major risks to premature morbidity and mortality.[6,7] People of lower socioeconomic status are more likely to smoke,[5] be sedentary[8] and eat a poor diet[9] compared to those of higher socioeconomic status. These behaviours have been suggested as mediators of the link between social position and health outcomes.[10-12]

Changing health behaviours

Given the potential improvements that changes in behaviour can bring to health, health research and clinical practice devotes considerable time and effort to behavioural interventions. For instance, stopping smoking increases life expectancy at any age and halves the risk of cardiovascular disease within one year.[13] Experts agree that major improvements in public health will be brought about through behaviour changes in the population.[7,14,15] Targeting behaviour change efforts at people at the lower end of the income spectrum is seen as a major means to reducing health inequalities. Gruer et al. (2009) [12 (p. 5)] for instance argued that 'the scope for reducing health inequalities related to social position […] is limited unless many smokers in lower social positions can be enabled to stop smoking.'

Health behaviour change in low-income populations

Existing behaviour change support for those disadvantaged by income may not be fit for purpose.[14] Evidence suggests that people from low-income groups are more difficult to identify and successfully recruit to general population interventions.[16-18] Moreover, it has been suggested that low-income populations may achieve poorer behaviour change outcomes following interventions compared to more affluent participants, resulting in poorer health outcomes[19-21] and potentially leading to intervention-generated inequalities.[22]

In studies targeted at the whole population rather than specific subgroups, Michie et al. (2009)[23] have argued that observed differences in outcomes between socio-economic groups may reflect baseline differences in health behaviours, and that the interventions themselves may be effective across the socio-economic spectrum. In their review of interventions targeted specifically at those disadvantaged by income, examining controlled studies (with or without random allocation) published between 1995 and 2006, they found 13 relevant studies with 17 available comparisons. Approximately half of interventions were reported as effective relative to controls, but no meta-analysis was performed to estimate an overall effect size. At present, there is a lack of evidence on the effectiveness of interventions specifically targeting health behaviour change in low-income individuals.[24,25]

The aim of the current systematic review is to build on Michie et al.'s (2009)[23] work by (a) providing an updated review including studies published since 2006, (b) including only randomised controlled trials and (c) applying meta-analysis to estimate intervention effect sizes. We investigated whether studies of interventions targeted at participants from low-income groups are effective in changing diet, physical activity or smoking behaviour.

Methods

Eligibility criteria

A protocol for this review is not publicly available, however this article does reflect the relevant components of the PRISMA checklist for the reporting of systematic reviews. The article was submitted with a copy of the checklist confirming this.

Studies included in this review had to meet the following inclusion criteria:

- **Population:** *Adults aged 18 years and over, of low-income and from the general population.* Studies were considered to target a low-income group if they explicitly referred to their participants as 'low-income'. General population was defined as not belonging to a specific clinical group, such as those with diabetes or cardiovascular disease. Pregnant and overweight individuals were not considered to belong to a clinical group and were therefore included.
- **Interventions:** *Interventions targeting a change in smoking, eating and/or physical activity behaviours.* Studies could target a single behaviour or multiple behaviours in any combination.
- **Study design:** *Published Randomised Controlled Trials (RCTs) and Cluster Randomised Controlled Trials (cRCTs).* Control condition could be no intervention, a less intense intervention or an intervention with different content.
- **Outcomes***: Behavioural outcomes relevant to smoking cessation, healthy eating and physical activity without no restrictions on length of follow-up.* Self-reported individual-level behaviour, more 'objective' measures of behaviour and measures of behavioural change were all included, as in Michie et al. (2009).[23] Studies were excluded if reported data was unsuitable for meta-analysis.
- **Date:** *1995 onwards:* Studies published from 1995-2006 were identified by screening Michie et al. (2009)[23], the primary search was conducted from 2006 to end of 2011. We chose to focus on studies published within the previous 15 years to ensure relevance to current financial, social, health and healthcare climates.
- **Language:** *English language:* in line with Michie et al. (2009)'s review. [23]

Search strategy

We used studies from 1995-2006 which had been identified by Michie et al's (2009) review rather than running the search again because the previous review's search criteria were similar but broader than our own and should therefore include all articles relevant to the current review. Specific search strategies were created (see supplementary file 1, web-only data online) to search for studies published since Michie et al.'s (2009)[23] review of 1995-2006 papers. We searched eight databases: Medline, Embase, PsycINFO, ASSIA, CINAHL, Cochrane Controlled Trials, Cochrane Systematic Reviews and DARE Electronic Databases. Search strategies were based on Michie et al. (2009)[23] and included three components: low-income population terms (e.g. low-income, poverty, social class or socioeconomic status), terms for the three targeted health behaviours (e.g. physical activity, diet, smoking cessation, lifestyle, health behaviour, or weight reduction) and intervention-relevant terms (e.g. behaviour/behaviour change, health program, intervention, health promotion or program evaluation). The specific strategies were iteratively created and tailored to each database's reference terms with an experienced NHS Clinical Librarian (PM). One author (ERB) ran the final searches on 1st December 2011 (Jan 2006 – Dec 2011). In addition to the primary search, we checked the bibliography of each included study.

Study selection

One author (ERB) used the current review's inclusion criteria to screen the full texts of the 13 studies published between 1995 – 2006 included in Michie et al. (2009).[23] For the studies published from 2006 onwards ERB initially screened titles and abstracts, and obtained potentially relevant studies for full text screening. If no abstract was available the full text was scanned at this first screening stage. If no full text was retrieved, or screening information was missing, ERB contacted the corresponding study author requesting further information. NM screened a random sample of 10% of titles and abstracts from the studies from 2006 onwards (n=151), agreement was 94%. Later in the screening process, NM screened a random sample of 10% of full text articles assessed (n=10), agreement was 90%. The small number of disagreements were resolved through discussion.

Data collection process

Data were extracted using a pre-specified and piloted data extraction form based on Davidson et al.'s (2003)[26] criteria, including study design, target behaviour, participants, recruitment strategies, intervention content and outcome data. Risk of bias in individual studies was assessed based on standard criteria adapted from Avenell et al. (2004).[27] Where published supplementary materials were available they were used to assist data extraction (these are referred to in Table 1 online) and if information was missing, the corresponding author was contacted. When interventions targeted more than one behaviour then data were extracted for the different behaviours separately. ERB, SUD and MJ jointly extracted the outcome data.

Data were extracted for all reported time points. The primary outcome was behaviour or behaviour change following the end of the intervention. For the dichotomous smoking outcomes proportions were extracted (e.g. percent of sample reporting smoking abstinence for the last seven days). For continuous diet and physical activity outcomes means and standard deviations were extracted (e.g. mean portions of fruit and vegetables consumed per week). Where there was a choice of outcome measures, the outcome chosen was the primary behavioural outcome measure specified by the authors, measured by the most objective means (e.g. accelerometer data was preferred to self-reported minutes of physical activity) and adjusted for baseline differences if this had been seen as necessary by the authors.

Synthesis of results

Data from included studies were meta-analysed in RevMan (Version 5.2) using random effect models. For continuous diet and physical activity outcomes, standardised mean differences (SMD) were calculated using Hedges' *g*.[28] For dichotomous smoking outcomes, relative risk (RR) of smoking abstinence was calculated and examined using the Cochran-Mantel-Haenszel test.[29]

Where studies had multiple comparisons (several intervention arms or reported outcomes for different behaviours) or were cRCTs, participant numbers were adjusted in line with Cochrane recommendations.[30] Meta-analyses were conducted for the three behaviours separately at two time points: the most proximal time point post intervention and the longest follow-up time point where reported. A 95% confidence interval was used and $p<.05$ was taken as significant. Degree of inconsistency between studies was assessed using the I^2 statistic, with an I^2 >50% considered to signify heterogeneity.[27] This heterogeneity was explored by comparing independent subgroups of studies differing for two clinically relevant characteristics, following Cochrane Handbook recommendations[30]: interventions targeting women only vs. a mixed sex sample, and interventions targeting of a single behaviour vs. multiple behaviours. Publication bias was assessed by visually inspecting funnel plots.

Results

Study selection

A flow diagram is presented in Figure 1. We identified 2097 references from the database search along with the 13 studies identified in Michie et al.'s (2009)[23] review. After removing 590 duplicates and excluding 1417 references on the basis of title and abstract screening 103 full texts were screened, of which 97 full texts were successfully retrieved, as 5 articles had no full text and one was irretrievable. Full text screening initially led to the inclusion of 30 studies. Two further studies were identified from title screening reference sections, so that 32 studies with 42 comparisons met inclusion criteria.

---------- Figure 1 here ----------

Study characteristics

Participant identification and recruitment

Studies initially identified low-income participants through their place of residence (i.e. living within an identified deprived area), by belonging to certain ethnic groups identified by the authors as suffering income inequality, being registered on a financial support programme, through belonging to

a health clinic serving disadvantaged groups, by their employment (working in a manual workplace) or by an indicator of income (e.g. quintile on the electoral role). Table 1 (supplementary file online) describes how each study defined its study population as 'low-income'. Twenty-one studies reported having measured participants' income as part of the study. Varying thresholds and income groupings were applied, but most commonly, incomes below $15-20,000 USD (£8840-11,800) per year were considered 'low' and most studies reported that the majority of participants were in this category. Of the remaining 11 studies, seven recruited participants from financial support programmes which required beneficiaries' earnings to be equivalent or near to official USA poverty levels (which vary over time and depending on the individual's household size), two reported that the majority of participants held a manual, low wage occupation and the final two studies reported that participants' neighbourhoods had a high proportion of residents living in poverty.

Following initial identification, participants were recruited through face-to-face contact, via letter, telephone, via media advertisement or most commonly a mixture of methods. Face-to-face opportunities described were door-to-door neighbourhood recruitment, organisation of a community health fair, invitation at medical or social services appointments, or through presentations at schools or other community groups. Telephone calls were usually a follow-up method of contact. Media advertisements included posters in community venues, newspaper, radio and television advertisements. In the majority of cases, it was the study investigators who initiated these recruitment activities. Timeframe of recruitment varied from one day to over two years. Techniques used to engage low-income groups in participating were poorly specified: those most commonly reported were offers of material incentives (e.g. vouchers for signing up), prompts and cues (e.g. a fridge magnet with the study telephone number) or social support to facilitate participation (e.g. advising about crèche facilities).

Study design and participant characteristics

The characteristics of the 32 included studies are summarised in Table 1 (web-only data online). The majority (*k*=27) were conducted in the USA; the remaining studies were from the UK (*k*=3), Australia (*k*=1) and Chile (*k*=1). Twenty-five studies were RCTs; seven were cRCTs. Studies took place in community (*k*=19), health care (*k*=12) or workplace (*k*=1) settings. Six studies tested a dietary intervention, 6 studies tested a physical activity intervention, 14 studies tested a smoking intervention, and the remaining 6 tested interventions for multiple behaviours (5 tested diet and PA interventions, one tested diet and smoking interventions). Three studies had multiple intervention arms for one behaviour. In total, this yielded 15 interventions for the dietary meta-analysis, 11 interventions for physical activity meta-analysis and 16 for smoking meta-analysis. Each study randomised between 27 and 2549 participants, yielding a total of 16,012 participants across the 32 studies. Of the 31 studies specifying participants' sex, 17 targeted women exclusively and no study sampled only men. Women formed 72.7% of all participants. Mean average age of participants was 38.4, this ranged from 22.0 to 66.2 across study subgroups.

Intervention content

The content of interventions varied from provision of tailored self-help materials, to individual counselling or group programs, but was often complex and poorly described (Table 1 online). Control groups in the intervention tended to receive usual care, a less intense version of the intervention or an inactive version (e.g. non-tailored materials). Intervention duration varied from a single episode to two years; the mode duration was three months. The intervention facilitator was described in 16 studies. In 11 studies this was either a routine healthcare provider such as a nurse or general medical practitioner, or a 'non-routine' healthcare provider such as a psychologist, dietician or smoking counsellor. Of the remaining 5 studies, the facilitator was a peer educator in three studies and a study administrator in two.

Intervention outcomes

Twenty studies assessed the behavioural outcome using self-report; 12 studies included an objective measure relating to behaviour such as biochemically-confirmed smoking cessation. For dietary interventions, the primary outcome was fruit and vegetables consumed, grams of fat or calories from fat consumed per day. For physical activity, studies reported a wider range of outcomes including mean number of minutes or hours of moderate physical activity per week, metres walked in six minutes, or metabolic equivalent minutes of activity per week. Smoking studies reported the number of participants who were abstinent from smoking, such as for the last seven days, post-partum or for the previous six months. Studies differed in the delay between end of the intervention and most proximal assessment: this ranged from a few hours up to eight months. Thirteen studies included follow-up data beyond the end of intervention time point. Overall 19.6% participants did not complete final assessments.

Risk of bias within studies

Table 2 (web-only data online) details the risk of bias assessment of the included studies. Risk of bias was variable. The majority of studies did not describe random allocation concealment procedures, provided numbers but not reasons for dropouts, did not mention blinding of any party, and stated having used intention-to-treat analyses. There is therefore some risk of bias particularly during randomisation and surrounding blinding.

Quantitative data synthesis: Effectiveness of interventions

Diet

Study outcomes are included in Table 3 (web only data online). The fifteen dietary interventions were found to have an SMD of 0.19 [95% CI 0.13 to 0.24, I^2=18%] (Figure 2). Eight dietary interventions provided longer-term follow-up data, for 6-12 months post-baseline with combined SMD of 0.16 [95% CI 0.08 to 0.25, I^2=41%].

---------- Figure 2 here ----------

Physical Activity

Eleven physical activity interventions yielded an SMD of 0.18 [95% CI 0.02 to 0.33, I^2=75%] (Figure 3). Three interventions provided longer-term follow-up data 6-8 months post-baseline with a combined SMD of 0.17 [95% CI -0.02 to 0.37, I^2=0%].

Subgroup analyses suggested SMDs were not different [p=.78] in 4 interventions targeting women only [SMD 0.18, 95% CI -0.10 to 0.47, I^2=92%] compared to 7 with a mixed sex sample [SMD 0.14, 95% CI 0.00 to 0.27, I^2=0%]. Effects were larger [p<.001] in 6 interventions targeting physical activity only [SMD 0.28, 95% CI 0.12 to 0.43, I^2=37%] than 5 targeting multiple behaviours [SMD 0.00, 95% CI -0.07 to 0.08, I^2=0%].

---------- Figure 3 here ----------

Smoking

Sixteen smoking interventions were found to have a RR of smoking abstinence of 1.63 [95% CI 1.37 to 1.95, I^2=52%] (Figure 4). Nine interventions provided longer-term follow-up data for 3-12 months post-baseline. Positive intervention effects were not maintained, RR of smoking abstinence was 1.07 [95% CI 0.9 to 1.29, I^2=12%].

Subgroup analyses suggested RRs were not different [p=.21] in 8 interventions targeting women only [RR 1.48, 95% CI 1.15 to 1.90, I^2=38%] to 8 with a mixed sex sample [RR 1.86, 95% CI 1.44 to 2.40, I^2=9%]. Effects were more than doubled in 15 interventions targeting smoking only [RR 1.66, 95% CI 1.39 to 1.98, I^2=40%] compared to one intervention targeting multiple behaviours [RR 0.73, 95% CI 0.23 to 2.25] although the difference was not statistically significant (p=.16).

---------- Figure 4 here ----------

Publication bias

Visual inspection of funnel plots showed little evidence of publication bias.

Discussion

Summary of Evidence

We systematically reviewed the effectiveness of interventions targeted at changing the diet, physical activity or smoking of low-income groups. The review updates and extends a previous narrative review[23] by including recently published studies; incorporating RCTs only; and applying meta-analysis to examine intervention effect.

We identified 32 studies containing 42 dietary, physical activity and smoking interventions. Studies used a wide range of methods to identify and engage low-income participants. Most studies were conducted in the USA, contained mostly women and were often delivered by a healthcare professional. The quality of studies was variable with some risk of bias identified.

Our meta-analysis estimated a post intervention SMD of 0.19 for diet, 0.18 for physical activity interventions and a RR of smoking abstinence of 1.63 for smoking interventions. According to Cohen's effect size conventions,[31] the interventions had small positive effects on behaviour relative to controls. For studies reporting follow-up data, the small positive effects were maintained for diet (SMD 0.18) but not for physical activity (SMD 0.17) or smoking cessation (RR 1.07). However long-term effects are based on a small subset of studies. Exploration of the heterogeneity in physical activity and smoking interventions suggested larger effect sizes in studies which focussed on a single behaviour.

Implications of findings

We found small intervention effects on the behaviour of low-income groups compared to controls: in the dietary domain, this was equivalent to just under half a portion of fruit or vegetables per day difference. In addition, similar reviews not targeting low-income participants tend to reported larger effects. Four such reviews targeting adults in the general population[32-34] or obese adults with additional risk factors[35] reported larger effects for diet (SMD 0.31),[34] physical activity (SMD 0.28-

0.32)[32,34,35] and smoking (RR 2.17) interventions.[33] Although true comparison is not possible unless the same interventions were compared in different population groups, this does suggest that the effects of interventions may be smaller for low-income populations. If other population groups benefit more from current interventions, even than those specifically targeted at low-income groups, then we can expect an overall gradual widening of health inequalities, as has been reported.[2] Clearly research with more effective interventions is needed, including RCTs conducted in the UK, to increase our understanding of 'what works' for low-income groups.

Exploration of heterogeneity in physical activity and smoking showed a trend towards studies targeting a single behaviour being more effective than those targeting two behaviours. In the smoking domain only one study targeted both smoking and diet[36] and this was the study with the lowest overall effect size. This resonates with the argument that human self-regulation draws on limited resources[37,38] which may be best applied to one behaviour change target at a time. In contrast, studies including women only did not seem to vary widely in effectiveness from those with a mixed sex sample. Nevertheless there may be other unexplored sources of heterogeneity including other aspects of the delivery of interventions, such as those in the TIDIER checklist[39] or use of techniques from the recently published Behaviour Change Technique taxonomy v1.[40]

Limitations

This study was a systematic but not exhaustive review, for instance not including informally published reports or 'grey literature', which tend not to be indexed within conventional databases. It limited its scope to RCTs and cluster RCTs to gather the highest quality evidence available, but some authors argue that the gains from enhanced external validity in less well-controlled studies such as community-based interventions should not be ignored.[41] In common with similar reviews[42] methodological quality of studies was variable: for example few studies blinded participants, facilitators or outcome assessors to treatment group. However, blinding of treatment condition in behavioural interventions is notoriously difficult: this is a criticism common to many similar

reviews.[43] Definitions of and thresholds for 'low-income' varied somewhat between studies, reflecting the fact that there is no one agreed-upon 'cut-off' for low-income. Nevertheless this still seems a highly relevant deprivation indicator in our financial and social context, perhaps more so than others such as education level. Some studies reported that a substantial minority of participants included did not have a particularly low-income, reinforcing the difficulties of targeting low-income groups. The majority of studies were conducted in the USA, limiting generalisability to the UK context, although effect sizes for the UK studies were not amongst the largest or smallest suggesting they followed the general trends. The intervention and control conditions were generally poorly specified. Categorisation or coding of control group content was not possible, even though studies show that this may vary substantially and influence intervention outcomes.[44] A final caveat for our findings is that whilst we excluded a study where the authors advised us that the data were zero-inflated[45] this may have been true of other studies.

Conclusions

This systematic review with meta-analysis of randomised controlled interventions to improve the diet, physical activity or smoking behaviour of low-income groups found small positive effects of interventions on behaviour compared to controls, which persisted over time for diet. Despite research highlighting the urgent need for effective behaviour change support for people from low-income groups to assist in reducing health inequalities,[10-12] this review suggests that our current interventions for low-income groups are positive, but small, risking 'intervention-generated inequalities'.[22] Policy makers and practitioners alike should seek improved interventions for disadvantaged populations to change health behaviours in the most vulnerable people and reduce health inequalities.

What this paper adds

What is already known on this subject

- Low-income groups in the UK and elsewhere face substantial health inequalities compared to middle and high-income groups, in part caused by differences in diet, physical activity and smoking behaviours.
- There has been no quantitative evidence synthesis of whether interventions targeted at low-income groups in health, workplace and community settings are effective in changing diet, physical activity and smoking behaviours.

What this study adds

- Our meta-analysis of 32 Randomised Controlled Trials suggests that interventions in low-income groups tend to have small positive effects on dietary behaviour, physical activity and smoking compared to controls. These effects are maintained after the intervention for diet but not activity or smoking.
- Physical activity and smoking interventions were more likely to be effective if they focussed on helping people to change one behaviour at a time.
- The effects of behaviour change interventions in low-income groups are smaller than those reported for interventions in other population samples. Differential effectiveness across the socioeconomic spectrum may exacerbate health inequalities.

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Contributors

ERB and MJ had the original idea for the paper and designed the review method and analyses. PM assisted in design of search strategies. ERB, SUD, NM and MJ participated in study selection and data extraction. ERB and SUD conducted statistical analysis. ERB, SUD, NM and MJ participated in writing the manuscript. ERB is the guarantor for the study.

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Competing interest declaration

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available from the corresponding author) and we declare that none of the authors have competing interests to disclose. No authors have received support from any organisation for the submitted work, have financial relationships with any organisations that might have an interest in the submitted work in the previous years, or other relationships or activities that could appear to have influenced the submitted work

Data sharing

No additional data available

Independence of authors

The views expressed in this paper are those of the authors

Transparency declaration

The lead author (ERB) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Ethical approval

Not required

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Figures

Figure 1: Study selection flow diagram

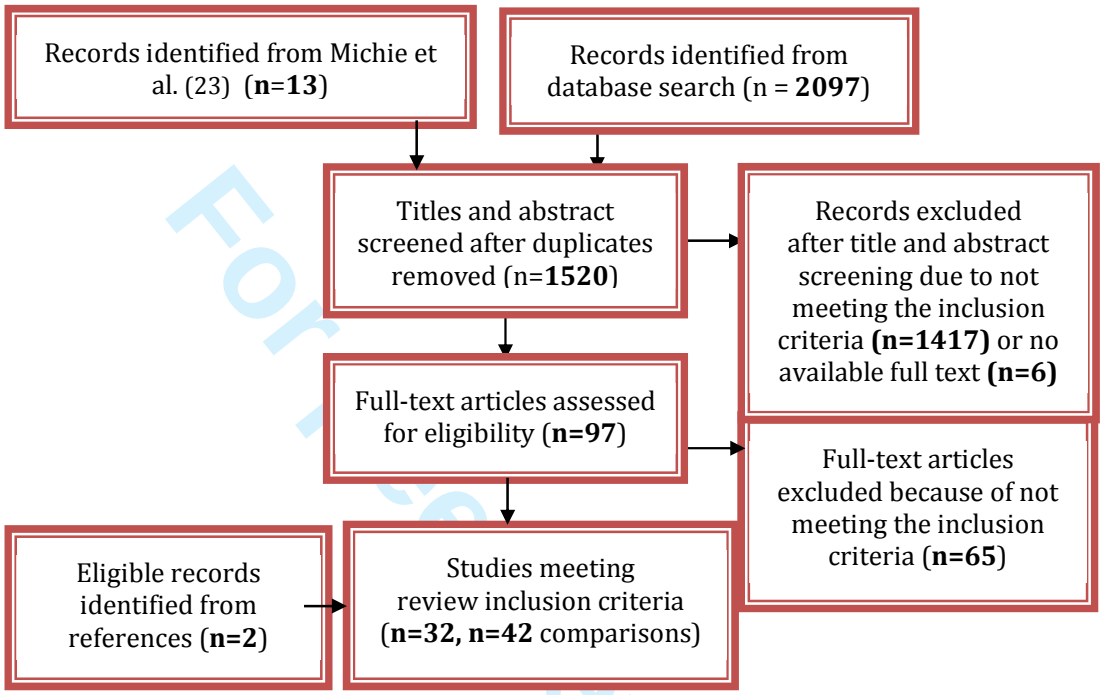


Figure 2: Standardised Mean Differences immediately post intervention for studies focusing on dietary change (ordered by effect size)

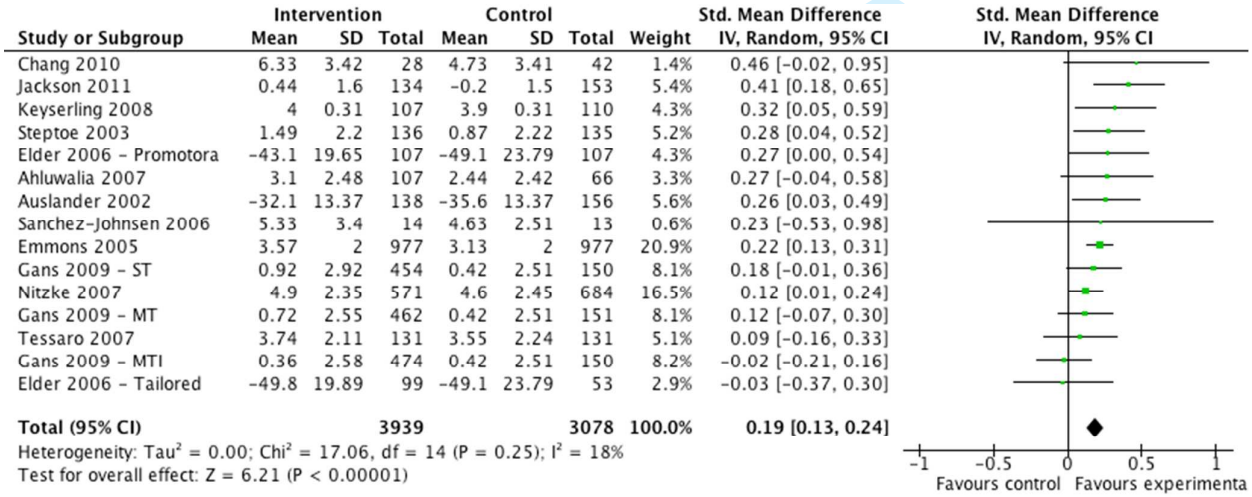


Figure 3: Standardised Mean Differences immediately post intervention for studies focusing on physical activity change, (ordered by effect size)

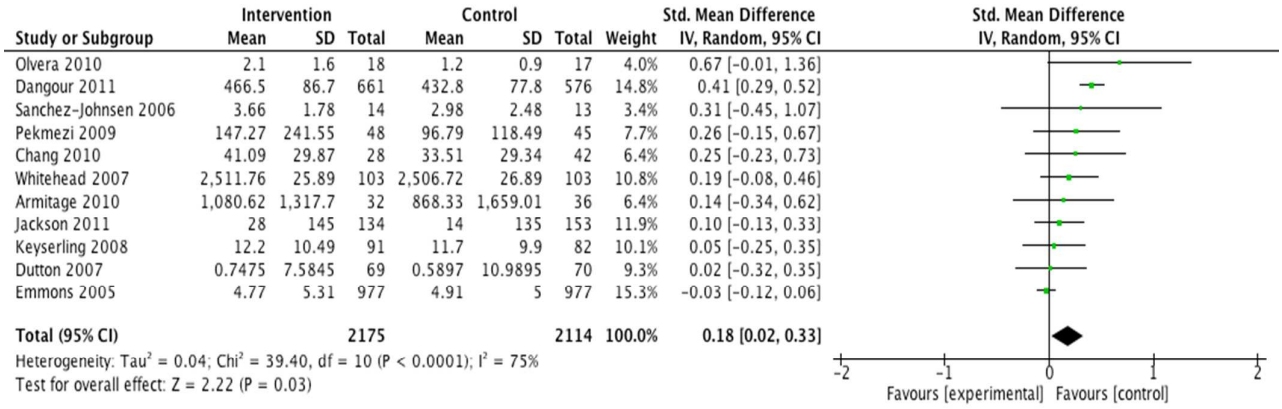
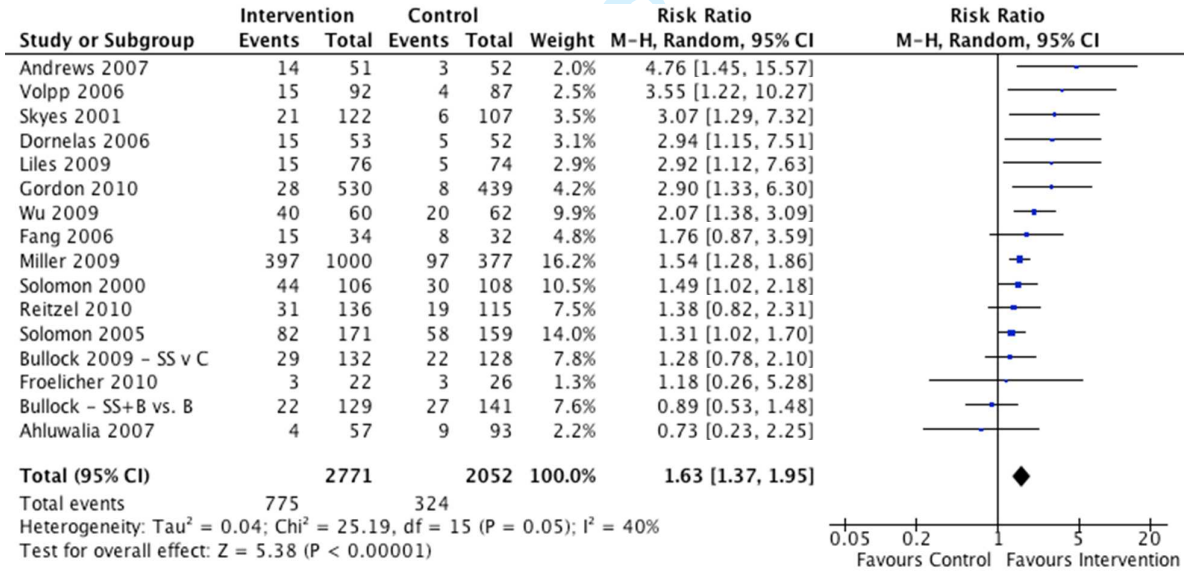


Figure 4: Relative Risk of smoking abstinence immediately post intervention for studies focusing on smoking interventions (ordered by effect size)



Supplementary Online materials (web-only data)

- **Supplementary file 1:** Example Search Strategy
- **Table 1:** Study Characteristics
- **Table 2:** Risk of bias
- **Table 3:** Study Outcomes
- **Supplementary file 5:** BMJ reviewer comments and responses

Supplementary File 1: Example Search Strategy

	Medline Database 1st December 2011	
1	exp poverty/	18153
2	exp poverty areas/	2800
3	exp social class/	15096
4	exp social conditions/	3188
5	"low income".ti,ab.	10169
6	1 or 2 or 3 or 4 or 5	40230
7	exp Life Style/	37377
8	exp weight gain/	14266
9	exp overweight/	77138
10	exp Weight Loss/	17681
11	exp obesity/	75542
12	exp food habits/	10789
13	exp fruit/	32639
14	exp vegetables/	47553
15	exp exercise/	45754
16	exp diet therapy/	16335
17	exp diet/	82764
18	exp Smoking/pc, px, th [Prevention & Control, Psychology, Therapy]	13314
19	exp smoking cessation/	14366
20	exp "Tobacco Use Cessation"/	14858
21	exp "Tobacco Use Disorder"/	5420
22	exp health behavior/	58129
23	"health behavio*".ti,ab.	6627
24	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23	
25	exp program development/	16327
26	exp program evaluation/	40639
27	exp intervention studies/	4265
28	exp health promotion/	32938
29	25 or 26 or 27 or 28	83647
30	6 and 24 and 29	728
31	limit 30 to (english language and yr="2006 -Current")	425

Table 1: Study characteristics: organised by behavioural target and then by alphabetical order of lead study author

Study ID, additional references, year and country of publication	Study design	Participants randomised ▪ N randomised and description ▪ Sex ▪ Age ▪ Reason for description of study population as 'low income'	Intervention description	Control description	Primary outcome	Main outcome time point and follow-up (weeks)
DIET						
Ahluwalia (diet) [46] Supplemented by Okuyemi et al. (2007) [47] 2007 USA	cRCT	▪ 173 smokers in a low-income public housing development ▪ 52 m, 121 f ▪ Mean age = 48 (13.1) ▪ 72.9-74.2% had individual income ≤$800/month	Motivational interviewing counselling, provision of fruit and vegetables, a cookbook and educational videos	Motivational interviewing for smoking and nicotine gum (see Ahluwalia smoking)	SR Portions of fruit and vegetables per day, last 7 days	6 months
Auslander[48] 2002 USA	cRCT	▪ 294 low-income overweight African American women ▪ Mean age ranged from 40.2 (8.2) to 41.2 (7.8) ▪ 60-70% below the poverty line (not defined). Mean family income $1,367.8 ±$1,047.0 to	Culturally-tailored peer-led dietary change program	No intervention until after final follow-up	SR mean % of calories from fat	Posttest: 3 month post baseline 6 month post baseline follow-up

		$1,619.1 ± $1,206.7/month				
Chang (diet)[49] Supplemented by Chang et al. 2009[50] 2010 USA	RCT	▪ 129 overweight and obese mothers from WIC sites ▪ Mean age ranged from 25.12 (4.10) - 25.53 (3.94). 18-34. ▪ Income not reported but mothers eligible for the Women, Infants and Children Supplemental Food and Nutrition Program (WIC) so have a household ≤185% of the federal poverty level, which in 2010 was $3677/month for a family of four*	DVD, peer support group and telephone calls	Usual care	SR cups of fruit and veg per day	2 month, 8 month 8 month follow-up
Elder [51] **(2 arms)** 2006 USA	RCT	▪ 257 low-income, Spanish-dominant Latina women ▪ Mean age = 39.71 (9.93) ▪ 53% had an individual income <$2000/month	**Tailored intervention:** Tailored mailed materials **Promotora intervention:** Tailored materials and weekly home visits/telephone	Non tailored, off the shelf materials	SR Mean grams of fat per day	M2 12 weeks M3 timepoint '6 m post-intervention' M4 timepoint '12m post-intervention'

			support			
Emmons (diet)[52] 2005 USA	cRCT	▪ 1954 low-income multi-ethnic adults ▪ 747 m, 1469f ▪ Age range 18-75 ▪ Income not reported but all participants lived in neighbourhoods classed as 'impoverished' (≥20% live below the federal poverty level)	Behavioural counselling, telephone support and mailings	Usual care: Not well specified	SR Fruit and veg servings per day	Endpoint
Gans[53] **(3 arms)** 2009 USA	RCT	▪ 1841 low-income ethnically diverse adults ▪ 275 m, 1566 f ▪ Mean age = 40.4 (12.9), 18-52 ▪ 56.4% individual income <$20,000/year	**Multiple Tailored (MT) intervention:** 4 tailored mailed educational packages +a DVD **Multiple Re-tailored (MTI) intervention:** 4 tailored educational packages based on telephone reassessments + a DVD	Non tailored nutrition information	SR Fruit and veg servings per day	4 month 7 months follow-up

			Single Tailored (ST) intervention: One tailored mailed educational package			
Jackson (diet)[54] 2011 USA	RCT	▪ 321 ethnically diverse low-income pregnant women ▪ Mean age 26.5 (6) ▪ Income not reported, but 85% of women received Medicaid, which in 2011 required pregnant women to have an individual income ≤$1862/month	Counselling via a virtual video-doctor	Usual care: prenatal care appointment	SR fruit and vegetable intake per day	4 weeks
Keyserling (diet)[55] Supplemented by Jilcott et al. (2006)[56] 2008 USA	RCT	▪ 236 low-income women from the WISEWOMAN program ▪ Mean age ranged from 52 (0.64) – 54 (0.66). ▪ Eligible for study if at or below 200% of the federal poverty level. 93-96% of participants had household income ≤$30,000/year	Counselling	Mailed diet and exercise leaflets	End point data: objectively measured fruit and veg intake, via median serum carotenoids (ug/dL) Follow-up data: fruit and vegetable consumption via Dietary Risk Assessment (score	6 month assessment 12 month assessment

					range 0-103, lower=healthier)	
Nitzke[57] Supplemented by Nitzke et al. 2004[58] 2007 USA	RCT	▪ 2024 low-income young adults ▪ 786 m, 1238 f ▪ Mode age 18. Age range 18-24. ▪ 60% had individual income <$800/month	Tailored nutrition materials	Non-tailored materials	SR Fruit and vegetable intake per day	12 months assessment
Sanchez-Johnsen[59] (diet) 2006 USA	RCT	▪ 27 overweight Latina women ▪ Mean age ranged from 43.2 (6.3) to 44.9 (8.2). 35-65 ▪ 52% family income <$16,000/year	Diet classes	Mailed health education	SR fruit and veg servings per day	6 week assessment
Steptoe[60] 2003 UK	RCT	▪ 271 adults from deprived areas ▪ Sex not specified ▪ Age range: 18-70 ▪ 68% had an individual income ≤£400 ($640) /week	Behavioural counselling sessions, tailored to motivation level	Non-tailored nutrition education counselling	SR fruit and veg servings per day	12 months
Tessaro[61] 2007 USA	RCT	▪ 395 low-income women ▪ Mean age 50.25 ▪ 67% household income <$20,000 /year	Computer-based interactive nutrition intervention	No intervention: waiting list control	SR fruit and veg servings per day	3 months

PHYSICAL ACTIVITY						
Armitage[62] 2010 UK	RCT	▪ 68 manual workers ▪ 35 m, 33 f ▪ Mean age = 27 (12.71) ▪ Income not reported, though all had manual or clerical job roles	Volitional help sheet with implementation intentions	Help sheet without implementation intentions	SR metabolic equivalent minutes exercise per week (MET minutes)	1 month
Chang (Physical activity)[49] 2010 USA Supplemented by Chang et al. 2009[50]	RCT	*See Chang (diet) above for description of the study's participants*	DVD, peer support group and telephone calls	Usual care	SR metabolic equivalent minutes exercise per week (MET minutes)	2 months 8 month follow-up
Dangour[63] 2011 Chile Supplemented by Dangour et al.	cRCT	▪ 1897 older adults registered with health centres in low-middle socioeconomic status municipalities ▪ 656 m, 1346 f ▪ Mean age ranged from 66.1 (0.9) – 66.2 (1.0). 64-67.9	Physical activity program	Educational materials on healthy eating, and information about healthcare provision	Objectively measured walking capacity: metres walked in six minutes	24 month assessment

(2007)[64]		▪ Income not reported, but all attended health centres where median 9.2% of the population live in poverty (per capita income less than twice the price of a basic basket of food in Chile)				
Dutton[65] 2007 USA	RCT	▪ 158 overweight low-income African American women ▪ Mean age = 41.73 (12.25) ▪ Participants eligible if individual income <$16,000 /year	Tailored weight loss intervention	Usual care	SR hours exercise per week	Post-treatment
Emmons[52] (physical activity) 2005 USA	cRCT	*See Emmons (diet) above for description of the study's participants*	Behavioural counselling and telephone support and mailings	Usual care? Not well specified	Mean hours per week of physical activity	Endpoint
Jackson[54] (Physical activity) 2011 USA	RCT	*See Jackson (diet) above for description of the study's participants*	Counselling via a virtual video-doctor	Usual care: pre-natal care appointment	SR minutes per week of physical activity	4 weeks
Keyserling[55] (Physical activity)	RCT	*See Keyserling (diet) above for description of the study's participants*	Counselling	Mailed leaflets	Objectively measured PA; accelerometer	6 month assessment

2008 USA Supplemented by Jilcott et al. (2006)[56]					moderate minutes per day	12 months follow-up
Olvera[66] 2010 USA Supplemented by Olvera et al. (2008)[67]	cRCT	▪ 46 low-income Latina mothers ▪ Mean age ranged from 33.3 (4.6) – 38.2 (10.6) ▪ 76% family income <$20,000 /year	Exercise and counselling	Same but 12 not 36 sessions	SR activity level on a scale from 0 (sedentary) to 7 (vigorous)	12 week assessment
Pekmezi[68] 2009 USA	RCT	▪ 93 Underactive Latina women ▪ Mean age = 41.37 (11.18), 18-65 ▪ 75% household income <$30,000 /year	Tailored monthly mailings on physical activity	6 monthly mailings on other topics	SR minutes physical activity per week	6 months
Sanchez-Johnsen[59] (Physical activity) 2006 USA	RCT	*See Sanchez-Johnsen (diet) above for description of the study's participants*	Exercise classes	Mailed health education	SR times engaged in activity designed to improve fitness on a scale from 1 (0 times) to 9 (more than 7 times)	6 week assessment

Whitehead[69] 2007 USA	RCT	▪ 206 low-income African Americans ▪ 36 m, 171 f ▪ Average age 50 ▪ 64% household income <$1000 /month	Mailed tailored physical activity information	Mailed non tailored information about a low-sodium diet	SR time spent in physical activities for last 7 days, yielding an estimated caloric expenditure	1 month assessment 6 month assessment follow-up
SMOKING						
Ahluwalia[46] (Smoking) 2007 USA Supplemented by Okeyumi et al. 2007[47]	RCT	▪ 173 smokers in a low-income public housing development ▪ 52 m, 121 f ▪ Mean age = 48 (13.1) ▪ 72.9-74.2% had individual income ≤$800/month	Motivational interviewing counselling for smoking and nicotine replacement therapy (NRT)	Motivational interviewing counselling, provision of fruit and vegetables, a cookbook and educational videos (see Ahluwalia, diet, above)	Biochemically confirmed smoking abstinence 7 days	6 month assessment
Andrews[70] 2007	RCT	▪ 103 African American women from a subsidised housing development.	Counselling, NRT and community health worker	Smoking print materials, group education on	Biochemically confirmed smoking abstinence 7 days	6 month assessment

USA Supplemented by Andrews et al. (2005)[71]		▪ Mean age = 40.2 (11.8), 18-85 ▪ Mean household income $689/month, range $0 to $2,300 /month	sessions	other topics		
Bullock[72] **2 arms** 2009 USA	RCT	▪ 695 women attending Women Infant and Children Nutritional Supplement (WIC) clinic ▪ Mean age = 22 (4.6) ▪ Income not reported but all women were eligible for WIC program so have household monthly gross income of ≤185% of the federal poverty level (see also Chang participant description)	**Social Support (SS) intervention:** Telephone calls from a nurse and 24 access through a pager **Social Support plus booklets (SS+B) intervention:** Same with eight mailed booklets on stopping smoking in pregnancy	**Booklets alone (B) control intervention:** Eight mailed booklets on stopping smoking in pregnancy **Control (C) intervention:** no intervention	Biochemically confirmed smoking abstinence last 7 days	End of pregnancy (T2) Post-delivery follow up (T3)
Dornelas[73] 2006 USA	RCT	▪ 105 pregnant smokers from a non-profit tertiary care community hospital ▪ Mean age = 26.1(5.8), 18-42 ▪ 49% household income of	Counselling session and telephone follow-up	Usual care: standard smoking cessation advice	Biochemically confirmed smoking abstinence for previous 7 days	End of pregnancy assessment Six months post-

		≤$15,000/year.				partum follow-up
Fang[74] 2006 USA	RCT	▪ 66 low-income Chinese and Korean smokers ▪ 63 m, 3 f ▪ Mean age ranged from 43.97 (17.21) to 48.35 (16.47) ▪ 68% had individual income ≤$15,000/year	Motivational interviewing style session + NRT	General health counselling, an educational booklet +NRT	SR smoking abstinence, last 7 days	1 week assessment 1 month and 3 month follow-up
Froelicher[75] 2010 USA	cRCT	▪ 60 African Americans from a low-income neighbourhood with high health disparities ▪ 17 m, 43 f ▪ Mean age = 46 (10.8) ▪ 55.9-61.5% individual income <$15,000/year	Smoking cessation program and tobacco industry and media messages handouts	Standard smoking cessation program and written hand-outs	Biochemically confirmed abstinence	6 month assessment 12 months follow-up
Gordon[76] 2010 USA	cRCT	▪ 2549 smokers visiting public dental clinics serving people of low-income ▪ 1241 m, 1508 f ▪ Mean age = 40.5 (12.6) ▪ Income not reported but participants at or below 200% of	Brief smoking advice	Usual care	SR smoking abstinence for last 6 months	7.5 months end point

		the federal poverty threshold as defined by the US Census Bureau 2006-8. This equates to an individual income ≤$19,600 /year*				
Liles [45] 2009 USA	RCT	▪ 150 low-income mothers who smoke from WIC programme ▪ Mean age 30.1 (7.1) ▪ Income not reported but all eligible for WIC program so have household monthly gross income of ≤185% of the federal poverty level (see also Chang participant description)	Counselling to decrease second-hand smoke exposure	Not specified	Biochemically confirmed quit for at least 7 days over study period	18 month assessment
Miller[77] 2009 Australia	RCT	▪ 1377 disadvantaged smokers ▪ Age not specified ▪ Income not reported but all participants were eligible for an Australian Government concession card, which currently requires an individual income of <$2,072AUS/month ($1948 US dollars)**	Availability of a quitline and NRT	Availability of a quitline without NRT	SR smoking abstinence: previous day	3 month assessment 6 months and 12 months follow-up

Reitzel[78] 2010 USA	RCT	▪ 251 low-income pregnant ex-smokers ▪ Mean age 24.6 (5.3) ▪ 55% household income <$30,000/year	Motivation and problem solving intervention	Usual care: self-help materials and guideline-based relapse prevention advice	Biochemically confirmed smoking abstinence following delivery of baby	Follow-up week 26 post-partum
Solomon[79] 2000 USA	RCT	▪ 214 medicaid-eligible female smokers of childbearing age ▪ Mean age 33 (8.5) ▪ Mean individual income $12,802 /year	3 months of telephone support and NRT	NRT only	Biochemically confirmed smoking abstinence: previous seven days	3 months 6 months follow-up
Solomon[80] 2005 USA	RCT	▪ 330 low-income women smokers ▪ Mean age ranged from 33.7 (8.9) to 34.8 (8.2) ▪ Income not reported, but all receiving Medicaid (see Jackson description) or Vermont Health Assistance Plan for low-income Vermonters (not further specified)	3 months of telephone support for psychosocial issues surrounding quitting and NRT	NRT only	SR smoking abstinence, last 7 days or 30 days	3 months 6 months follow-up
Sykes[81] 2001	RCT	▪ 260 adult smokers from a deprived area ▪ 94 m, 166 f	Quit for life self-help cognitive behavioural programme	Usual care 'stopping smoking made	Biochemically confirmed smoking abstinence: previous	Follow-up outcome point

UK		▪ Age not specified ▪ Income not reported, 42% in manual occupation or unemployed and therefore defined as 'low-income'		easier' booklet	seven days	
Volpp[82] 2006 USA	RCT	▪ 179 low-income veteran smokers ▪ 168 m, 10 f ▪ Mean age ranged from 52.7 to 53.1 ▪ 49.7% household income <$15,000 /year	Free smoking cessation program +financial incentives for attending class and quitting smoking	The same program without incentives	Biochemically confirmed smoking abstinence: previous seven days	30 day assessment 6 months follow-up
Wu[83] 2009 USA	RCT	▪ 139 low-income Chinese American smokers ▪ 107 m, 15 f ▪ Mean age ranged from 43.9 (12.1) – 45 (12.8) ▪ 72%-77% individual income <$20,000 /year	Motivational interviewing counselling for smoking	General health counselling	Biochemically confirmed quit at follow-up	6 month assessment

Note. RCT=randomised controlled trial. cRCT= cluster randomised controlled trial. SR=self-reported. If a study had multiple arms testing interventions for one behaviour, they are listed under one section in the table. If the study included interventions with the same participants for more than one behaviour, the characteristics for each intervention are reported separately for the relevant behavioural target *Source: http://familiesusa.org/product/federal-poverty-guidelines retrieved 14.06.14 ** Source: http://www.humanservices.gov.au/customer/enablers/centrelink/low-income-health-care-card/income-test, retrieved 14.06.14

Table 2: Risk of bias for individual studies, in alphabetical order (following Avenell et al. 2004).[27]

	Lead study author	Quality of random allocation concealment	Description of withdrawals and drop outs	Intention to treat analysis?	Participants blinded to treatment status?	Intervention facilitators blinded to treatment status?	Outcome assessors blinded to treatment status?
1	**Ahluwalia**[46]	A	Numbers and reasons	Yes	Bi	C	C
2	**Andrews**[70]	C	Numbers stated only	Yes	Bi	Bi	Bi
3	**Armitage**[62]	C	Numbers stated only	Yes	Ai	Ai	C
4	**Auslander**[48]	C	Numbers stated only	No	Bi	Bi	Bi
5	**Bullock**[72]	Bi	Numbers and reasons	Yes	Ai	C	Ai
6	**Chang**[49]	Bi	Numbers and reasons	No	Aii	Aii	Bi
7	**Dangour**[63]	Bi	No numbers given	Yes	C	C	Ai
8	**Dornelas**[73]	Bi	Numbers and reasons	Yes	Bi	Bi	Bi
9	**Dutton**[65]	Bi	Numbers and reasons	Not clear	C	C	C
10	**Elder**[51]	Bi	Numbers and reasons	No	C	Bi	Bi
11	**Emmons**[52]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
12	**Fang**[74]	C	Not mentioned	Yes	C	C	C
13	**Froelicher** [75]	Bi	Numbers stated only	Yes	C	C	Bii
14	**Gans**[53]	A	Numbers and reasons	Yes	Bi	Bi	Aii
15	**Gordon**[76]	Bi	Numbers stated only	No	Bi	Bi	Bi
16	**Jackson**[54]	A	Numbers and reasons	Yes	C	Ai	C
17	**Keyserling**[55]	A	Numbers and reasons	Yes	Bi	Bi	Bi
18	**Liles**[45]	Bi	Numbers stated only	Yes	Bi	Bi	Ai
19	**Miller**[77]	Bi	Numbers stated only	Yes	C	Bi	C

20	**Nitzke**[57]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
21	**Olvera**[66]	Bi	Numbers and reasons	No	Bi	Bi	Bi
22	**Pekmezi**[68]	Bi	Numbers and reasons	Yes	Bi	Bi	Bi
23	**Reitzel**[78]	Bi	Numbers stated only	Yes	C	C	C
24	**Sanchez-Johnsen**[59]	Bi	NA	NA	Bi	Bi	Bi
25	**Steptoe**[60]	C	Numbers stated only	Yes	Ai	C	C
26	**Tessaro**[61]	C	Numbers stated only	No	Bi	Bi	Bi
27	**Soloman**[79]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
28	**Soloman**[80]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
29	**Sykes**[81]	Bii	Numbers stated only	No	Ai	Ai	Bi
30	**Volpp**[82]	A	Numbers stated only	Yes	C	Ai	C
31	**Whitehead**[69]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
32	**Wu**[83]	Bi	Numbers and reasons	No	C	C	C

Note. *NA=not applicable*

Quality of random allocation concealment:
A = good attempt at concealment
Bi = states random allocation but no description given
Bii= attempt at concealment but real chance of disclosure of assignment prior to formal trial entry
C = definitely not concealed

Blinding:
Ai = action taken at blinding likely to be effective
Aii = blinding stated but no description given
Bi = no mention of blinding
Bii = attempt at blinding but reason to think it may not have been successful
C = not blinded

Table 3: Intervention outcomes: organised by behavioural target and then by alphabetical order of lead study author

Study reference and follow-up point	Outcome measure	Control group baseline mean n (SD/SE)	Intervention group baseline mean (SD/SE)	Control group endpoint mean (SD/SE) or proportion abstinent from smoking	Intervention group endpoint mean (SD/SE) or proportion abstinent from smoking	Follow-up outcome mean (SD/SE) or proportion abstinent from smoking	Intervention effect as reported in the paper
DIET							
Ahluwalia[46] (diet) 6 month	SR Portions of fruit and vegetables per day, last 7 days	2.17 (1.63)	2.06 (1.73)	2.44 (2.42)	3.10 (2.48)		▪ Mixed linear model found significant difference between groups (p=.04)
Auslander[48] (diet) Post test: 3 month post baseline	SR mean % of calories from fat	36%	35.9%	35.6%	32.1%	6 month follow-up **C** 34.5% **IV** 32.3%	▪ ANCOVA test and post-hoc tests revealed significant difference between intervention and control group at 3 month post test [t=-4.01 p<.01] and 6 month follow-up –[2.50 p<.05]
Chang[49] (diet) 2 months	SR cups of fruit and vegetables per day	4.25 (2.91)	4.87 (4.41)	4.73 (3.41)	6.33 (3.42)	8 month follow-up **C** 5.56 (3.50) **IV** 3.87 (3.52)	▪ General linear mixed model found no significant intervention effect at either time point p>.05
Elder[51] **(2 arms)**	SR Mean grams of fat per day	56.8 (SD25.2)	**Tailored IV group**	49.1 (SE1.9)	**Tailored IV group** 49.8	M3 time point 6 months post-	▪ Significant differences between groups reported at

M2 time point 12 weeks			59 (SD28.6) **Promotora IV group** 60.2 (SD26.6)		(SE2) **Promotora IV group** 43.1 (SE1.9)	<u>intervention'</u> **C** 48.2 (SE2.0) **tailored IV** 50(SE2) **promotora IV** 46.4 (SE2) <u>M4 timepoint '12 months post-intervention'</u> **C**51.9 (SE2.3) **tailored IV** 45.3 (SE2.4) **promotora IV** 50.4 (SE2.3)	M2 [$F(2.309)$=3.73, p=0.025] Group differences were not maintained at M3 or M4 (not further specified).
Emmons[52] (diet) Endpoint	SR Fruit and veg servings per day	3.19 (SE0.062)	3.28 (SE0.062)	3.13 (SE0.064)	3.57 (SE 0.064)	-	▪ Significantly greater changes in **IV** group than **C** group p=.005
Gans[53] **(3 arms)** 4 months	SR Fruit and veg servings per day	NS	NS	Change from baseline 0.42 (2.51)	Change from baseline **MT IV group** 0.72 (2.55) **MTI IV group** 0.36 (2.58)	<u>7 months</u> **C** 0.24 (2.52), **MTIV** 0.68 (2.63), **MTI IV** 0.49 (2.58) **ST** 0.58 (2.69)	▪ At 4 months significant differences between **C** and **ST** (p=.01), **ST** and **MTI** (p=.01), **MT** and **MTI** (p=.01), **C** and **MT** (p=.05) ▪ At 7 month follow-up, only

					ST IV group 0.92 (2.92)		significant differences between **C** and **MT** (*p*=.02)
Jackson (diet)[54] 4 weeks	SR fruit and vegetable intake per day	3.3 (1.7)	3.0 (1.6)	3.1 (1.5) change of -0.2 (1.5)	3.44 (1.6) change of +0.44 (1.6)	-	▪ T test showed significant difference between groups p<.001
Keyserling[55] (diet) 6 month assessment	End point data: objectively measured fruit and veg intake, via median serum carotenoids (ug/dL) Follow-up data: fruit and vegetable consumption via Dietary Risk Assessment (score range 0-103, lower=healthier)	3.8(SE0.05)	3.8(0.06)	3.9 (SE0.03)	4.0 (SE0.03)	12 month assessment: **C** 32.8(SE0.7) **IV** 29.2 (SE0.7)	▪ Marginally significant difference between adjusted mean objective measures at 6 month assessment (*p*=.05) ▪ Significant difference at follow-up12 month assessment for Dietary Risk Scores (*p*<.001)
Nitzke[57] 12 months assessment	Daily fruit and vegetable intake, servings	4.72(2.61)	4.75 (2.86)	4.60 (2.45)	4.90 (2.35)	-	▪ Significant intervention effect from ANOVA [*F*=3.49, p<.05]
Sanchez-Johnsen (diet)[59]	SR fruit and veg servings per day	6.11(3.11)	5.66 (3.80)	4.63 (2.51)	5.33 (3.40)	-	▪ ANOVA test suggested significant intervention effect

6 week assessment							[F=4.716, p=.04]
Steptoe[60] 12 months	SR fruit and veg servings per day	3.67 (2.0)	3.6 (1.81)	0.87 (2.22)	1.49 (2.2)	-	▪ Significant difference in change =0.62 servings, [p=.021, 95% CI 0.09 to 1.13)]
Tessaro[61] 3 months	SR fruit and veg servings per day	3.87 (1.90)	3.90 (1.89)	3.55 (2.24)	3.74 (2.11)		▪ Paired t test indicated no significant difference between 3 month follow-up scores (p=.32)
PHYSICAL ACTIVITY							
Armitage[62] 1 month	SR metabolic equivalent minutes exercise per week (MET mins)	896.89 (1657.94)	733.12 (945.15)	868.33 (1659.01)	1080.62 (1317.70)	-	▪ Significant intervention effect according to ANCOVA analysis [F(1,66)=7.28, p=.009]
Chang (Physical activity)[49] 2 months	SR metabolic equivalent minutes exercise per week (MET mins)	27.28 (29.85)	29.76 (26.74)	33.51 (29.34)	41.09 (29.87)	8 month follow-up **C** 36.02 (29.3) **IV** 53.20 (30.24)	▪ General linear mixed model, no significant effect at 2 months (effect size d=0.25, CI -0.24 to 0.74) or at 8 months (effect size d=0.57, CI -0.04 to 1.18)
Dangour[63] 24 month	Objectively measured walking	452.8 (78.4)	447.9 (72.4)	432.8 (77.8)	466.5 (86.7)		▪ Significant difference between groups (p=.001)

assessment	capacity: metres walked in six minutes						
Dutton[65] Post-treatment	SR hours exercise per week	NS	NS	Mean change from baseline: 0.59(10.99)	Mean change from baseline: 0.75 (7.58)		▪ ANOVA test found no significant difference between conditions (p=.65)
Emmons[52] (physical activity) Follow-up	SR Mean hours per week	4.93 (SE0.16)	4.8 (SE0.16)	4.91 (SE0.16)	4.77 (0.17).		▪ No significant differences between groups at follow-up [p=.51]
Jackson[54] (Physical activity) 4 weeks	SR minutes per week of physical activity	122 (SD not reported)	127 (SD not reported)	136 (135) [change of 14]	155 (145) [change of 28]		▪ Means not significantly different at 4 week follow-up according to an unpaired Student's t-test p=.42
Keyserling[55] (Physical activity) 6 month assessment	Objectively measured PA; accelerometer moderate minutes per day	13(SE1.2)	11.6 (SE1.3)	11.7(SE1.1)	12.2(SE1.1)	12 month follow-up **C**12.5(SE1.1), **IV** 11.0(SE1.1)	▪ Not significantly different according to ANCOVA, at 6 months [p=.74] or 12 month follow-up [p=.33]
Olvera[66] 12 week assessment	SR activity level on a scale from 0 (sedentary) to 7 (vigorous)	1.2 (1.5)	1.4 (0.9)	1.2 (0.9)	2.1 (1.6)		▪ No significant effect according to ANCOVA [F 1.35, p=2.57, d=.4]
Pekmezi[68]	SR minutes of	11.88	16.56	96.79 (118.49)	147.27 (241.55)		▪ No significant between group

6 months	physical activity per week	(21.99)	(25.76)				differences according to ANOVA [$F(1,91)=1.37$, $p=.25$]
Sanchez-Johnsen[59] (Physical activity) 6 week assessment	SR times engaged in activity designed to improve fitness on a scale from 1 (0 times) to 9 (more than 7 times)	2.11 (2.18)	2.11 (1.75)	2.98 (2.48)	3.66 (1.78)		▪ No significant difference according to ANCOVA [$F=0.634$, $p=.434$]
Whitehead[69] 1 month assessment	SR time spent in physical activities for last 7 days, yielding an estimated caloric expenditure	2507.82 (SE 2.64)	2507.35 (2.55 SE)	2506.72 (2.65)	2511.76 (2.56)	6 month assessment **C** 2507.67 (2.98) **IV** 2511.2 (2.89)	▪ A doubly multivariate ANOVA with planned comparisons showed significant differential group changes at 1 month [$F(1,205)=17.98$, $p<.001$] and 6 months [$F(1,205)=4.07$, $p<.05$]
SMOKING							
Ahluwalia[46] (Smoking) 6 month	Biochemically confirmed smoking abstinence	All smoked at baseline	All smoked at baseline	9 of 93 abstinent	4 of 57 abstinent	-	▪ Adjusted Mantel-Haenszel chi-square statistic revealed no significant difference between groups ($p=.73$).

assessment	7 days						
Andrews[70] 6 month assessment	Biochemically confirmed smoking abstinence 7 days			3 of 52 abstinent	14 of 51 abstinent	-	▪ Odds ratio 4.9, CI -1.51 to 15.89 ▪ Main effect of intervention group variable in multiple regression, *p*=.001.
Bullock[72] **2 arms** End of pregnancy (T2)	Biochemically confirmed smoking abstinence last 7 days			**B control group** 27 of 141 **C control group** 22 of 128	**SS+B IV group** 22 of 129 **SS IV group** 29 of 132	Post-delivery follow up (T3) **B control group** 19 if 141 **C control group** 17 of 128 **SS+B IV group** 16 of 129 **SS IV group** 15 of 132	▪ Likelihood ratio chi-square not significantly different X^2=1.33, p=.72 at T2 end of pregnancy X^2=1.39, p=.71 at T3 post-delivery follow-up
Dornelas[73] End of pregnancy assessment	Biochemically confirmed smoking abstinence for previous 7 days	-	-	5 of 52	15 of 53	Six months post-partum **C**2 of 52 **IV** 5 of 53	▪ Significant difference at end of pregnancy assessment only, according to chi-squared test X^2=5.94(1), *p*=.015.
Fang[74] 1 week assessment	SR smoking abstinence, last 7 days	-	-	8 of 32	15 of 34	1 month **C**10 of 32, **IV** 19 of 34 3 months	Intervention and Controls not significantly different at 1 week follow-up according to chi-square test X^2(1)=2.51,

						C9 of 32, **IV** 16 of 34	*p*=.11. Significant differences at 1 month [$X^2(1)=4.06$, p<0.05] but not at 3 months [$\chi^2(1)=2.51$, *p*=0.11]
Froelicher[75] 6 month assessment	Biochemically confirmed abstinence	-	-	3 of 26	3 of 22	12 months **C**1 of 19, **IV** 3 of 19	▪ Not significantly different – not further specified.
Gordon[76] 7.5 months end point	SR smoking abstinence for last 6 months	-	-	8 of 439	28 of 530	-	▪ Significant between groups effect [*F*(1,12)=14.62, *p*<.01].
Liles[45] 18 month assessment	Biochemically confirmed quit for at least 7 days over study period	-	-	5 of 74	15 of 76	-	▪ Fisher's exact test: difference statistically significant *p*=.029
Miller[77] 3 month assessment	SR smoking abstinence: previous day	-	-	97 of 377	397 of 1000	6 months **C**80 of 377, **IV** 309 of 1000 12 months **C**83 of 377 **IV** 191 of 1000	▪ Chi squared test: significant difference reported at 3 and 6 month assessment [*p*≤.001] but not at 12 months [*p* value not specified]
Reitzel[78] Follow-up week	Biochemically confirmed smoking	None smoked at baseline	None smoked at baseline	19 of 115	31 of 136		▪ Main effect of treatment approached significance according to a continuation

26 post-partum	abstinence following delivery of baby	(relapse prevention interventio n)	(relapse prevention intervention)				ratio logit model [$X^2(1)=3.10$, $p=.08$]
Solomon 2000[79] 3 months	Biochemically confirmed smoking abstinence: previous seven days	-	-	30 of 108	44 of 106	6 months **C**20 of 108 **IV** 24 of 106	• Experimental condition strongest predictor in logistic regression at 3 months: OR 2, CI 1.09 TO 3.68. Not a significant predictor at 6 month follow-up (not further specified)
Solomon 2005[80] 3 months	SR smoking abstinence, last 7 days	-	-	58 of 159	82 of 171	6 months **C** 48 of 159 **IV** 65 of 171	• Significant difference at 3 months [$p=.035$] according to Chi square test but not at 6 month follow-up [p value not specified]
Sykes[81] Follow-up	Biochemically confirmed smoking abstinence: previous seven days	-	-	6 of 107	21 of 122		• Significant difference compared to controls [$X^2(2)=22.339$, $p<.001$]
Volpp[82]	Biochemically	-	-	4 of 87	15 of 92	6 months	▪ Significant difference at 30

30 day assessment	confirmed smoking abstinence: previous seven days					**C** 4 of 87 **IV** 6 of 92	day assessment according to Chi squared test [X^2=6.46, p=.01], but not at 6 month assessment [X^2 = 0.31, p= 0.57]
Wu[83] 6 month assessment	Biochemically confirmed quit at follow-up	-	-	20 of 62	40 of 60	-	▪ Significant difference according to logistic regression, OR 4.32, CI: 2.01 to 9.27, p<.001

Note. SR=self-reported NS=not specified, **C**=control group **IV**= intervention group SE=standard error, OR=odds ratio, CI=confidence interval. p<.05 was considered statistically significant. Unless otherwise specified, in smoking interventions no participants were abstinent from smoking at baseline

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5-6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7-8
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supplementary file 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	9
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	9-10
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	9-10

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	10
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	10
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-11 (&Table 1)
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	13
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	13-14 (and table 3)
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	13-14
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	14
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	13-14
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	15-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	16-17
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	17
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	20

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PRISMA 2009 Checklist

BMJ Open

Are interventions for low-income groups effective in changing healthy eating, physical activity and smoking behaviours? A systematic review and meta-analysis

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Are interventions for low-income groups effective in changing healthy eating, physical activity and smoking behaviours? A systematic review and meta-analysis

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MeSH term Keywords: Health behaviour, health promotion, poverty, social class, food habits, exercise, tobacco use, tobacco use cessation

Word count: 3957 (including introduction, methods, results and discussion)

Abstract

Objective: To conduct a systematic review and meta-analysis examining the effectiveness of behavioural interventions targeting diet, physical activity or smoking in low-income adults.

Design: Systematic review with random effects meta-analyses. Studies before 2006 were identified from a previously published systematic review (searching 1995-2006) with similar but broader inclusion criteria (including non-randomised controlled trials). Studies from 2006 to 2014 were identified from eight electronic databases using a similar search strategy.

Data sources: Medline, Embase, PsycINFO, ASSIA, CINAHL, Cochrane Controlled Trials, Cochrane Systematic Review and DARE.

Eligibility criteria for selecting studies: RCTs and Cluster RCTs published from 1995 to 2014; interventions targeting dietary, physical activity and smoking; low-income adults; reporting of behavioural outcomes.

Main outcome measures: Dietary, physical activity and smoking cessation behaviours.

Results: 35 studies containing 45 interventions with 17,000 participants met inclusion criteria. At post-intervention, effects were positive but small for diet [Standardised Mean Difference (SMD) 0.22, 95%CI 0.14 to 0.29], physical activity [SMD 0.21, 95%CI 0.06 to 0.36] and smoking [relative risk (RR) of 1.59, 95%CI 1.34 to 1.89]. Studies reporting follow-up results suggested that effects were maintained over time for diet [SMD 0.16, 95%CI 0.08 to 0.25] but not physical activity [SMD 0.17, 95%CI -0.02 to 0.37] or smoking [RR 1.11, 95%CI 0.93 to 1.34].

Conclusions: Behaviour change interventions for low-income groups had small positive effects on healthy eating, physical activity and smoking. Further work is needed to improve the effectiveness of behaviour change interventions for deprived populations.

Article Summary

Strengths and limitations of the study

- This was a comprehensive systematic review with meta-analysis to examine the effects of behavioural interventions in a deprived proportion of the population, namely those with a low income.
- We updated a previous review on this topic and focussed exclusively on evidence from RCTs, which are often termed 'the golden standard' of research.
- Applying meta-analysis enabled us to summarise the data quantitatively and estimate pooled effect sizes, which could be compared to those for interventions from other population groups.
- We searched for studies where participants were described as 'low-income' as this is a financially and socially relevant indicator of deprivation, but relevant papers not using this term may have been missed
- We searched for studies using a range of databases, but we may have missed relevant studies not indexed within the 'grey literature'.
- The majority of the studies were conducted in the USA, potentially limiting generalisability and did not tend to describe their intervention content comprehensively, making it difficult to further explore 'what works' for people with a low income.

Introduction

Health outcomes are strongly correlated with social position in societies across the western world: individuals from deprived backgrounds die younger and experience a greater proportion of their lives with a disability.[1-5] In the most deprived areas of England, for example, life expectancy is approximately eight years less, and disability-free life expectancy 15 years less than in the least deprived areas.[1] Amongst several deprivation indicators, a person's individual or household income is widely recognised as being strongly positively correlated with health outcomes[3]. The social gradient in health is predicted to steepen further[2] despite policy efforts aimed at maximising equality.[3-5]

Behaviours linked to health, particularly healthy eating, physical activity and smoking, show a similar social gradient to health outcomes. Consumption of tobacco, a poor diet and a lack of physical activity are major risks to premature morbidity and mortality.[6,7] People of lower socioeconomic status are more likely to smoke,[5] be sedentary[8] and eat a poor diet[9] compared to those of higher socioeconomic status. These behaviours have been suggested as mediators of the link between social position and health outcomes.[10-12]

Changing health behaviours

Given the potential improvements that changes in behaviour can bring to health, health research and clinical practice devotes considerable time and effort to behavioural interventions. For instance, stopping smoking increases life expectancy at any age and halves the risk of cardiovascular disease within one year.[13] Experts agree that major improvements in public health will be brought about through behaviour changes in the population.[7,14,15] Targeting behaviour change efforts at people at the lower end of the income spectrum is seen as a major means to reducing health inequalities. Gruer et al. (2009) [12 (p. 5)] for instance argued that 'the scope for reducing health inequalities related to social position […] is limited unless many smokers in lower social positions can be enabled to stop smoking.'

Health behaviour change in low-income populations

Existing behaviour change support for those disadvantaged by income may not be fit for purpose.[14] Evidence suggests that people from low-income groups are more difficult to identify and successfully recruit to general population interventions.[16-18] Moreover, it has been suggested that low-income populations may achieve poorer behaviour change outcomes following interventions compared to more affluent participants, resulting in poorer health outcomes[19-21] and potentially leading to intervention-generated inequalities.[22]

In studies targeted at the whole population rather than specific subgroups, Michie et al. (2009)[23] have argued that observed differences in outcomes between socio-economic groups may reflect baseline differences in health behaviours, and that the interventions themselves may be effective across the socio-economic spectrum. In their review of interventions targeted specifically at those disadvantaged by income, examining controlled studies (with or without random allocation) published between 1995 and 2006, they found 13 relevant studies with 17 available comparisons. Approximately half of interventions were reported as effective relative to controls, but no meta-analysis was performed to estimate an overall effect size. At present, there is a lack of evidence on the effectiveness of interventions specifically targeting health behaviour change in low-income individuals.[24,25]

The aim of the current systematic review is to build on Michie et al.'s (2009)[23] work by (a) providing an updated review including studies published since 2006, (b) including only randomised controlled trials and (c) applying meta-analysis to estimate intervention effect sizes. We investigated whether studies of interventions targeted at participants from low-income groups are effective in changing diet, physical activity or smoking behaviour.

Methods

Eligibility criteria

A protocol for this review is not publicly available, however this article does reflect the relevant components of the PRISMA checklist for the reporting of systematic reviews. The article was submitted with a copy of the checklist confirming this.

Studies included in this review had to meet the following inclusion criteria:

- **Population:** *Adults aged 18 years and over, of low-income and from the general population.* Studies were considered to target a low-income group if they explicitly referred to their participants as 'low-income'. General population was defined as not belonging to a specific clinical group, such as those with diabetes or cardiovascular disease. Pregnant and overweight individuals were not considered to belong to a clinical group and were therefore included.
- **Interventions:** *Interventions targeting a change in smoking, eating and/or physical activity behaviours.* Studies could target a single behaviour or multiple behaviours in any combination.
- **Study design:** *Published Randomised Controlled Trials (RCTs) and Cluster Randomised Controlled Trials (cRCTs).* Control condition could be no intervention, a less intense intervention or an intervention with different content.
- **Outcomes***: Behavioural outcomes relevant to smoking cessation, healthy eating and physical activity without no restrictions on length of follow-up.* Self-reported individual-level behaviour, more 'objective' measures of behaviour and measures of behavioural change were all included, as in Michie et al. (2009).[23] Studies were excluded if reported data were unsuitable for meta-analysis.
- **Date:** *1995-2014:* Studies published from 1995-2006 were identified by screening Michie et al. (2009)[23], the primary search included studies published between January 2006 and July 2014. We chose to focus on studies published within the previous two decades to ensure relevance to current financial, social, health and healthcare climates.
- **Language:** *English language:* in line with Michie et al. (2009)'s review. [23]

Search strategy

We used studies from 1995-2006 which had been identified by Michie et al's (2009) review rather than running the search again because the previous review's search criteria were similar but broader than our own and should therefore include all articles relevant to the current review. Specific search strategies were created (see supplementary file 1, web-only data online) to search for studies published since Michie et al.'s (2009)[23] review of 1995-2006 papers. We searched eight databases: Medline, Embase, PsycINFO, ASSIA, CINAHL, Cochrane Controlled Trials, Cochrane Systematic Reviews and DARE Electronic Databases. Search strategies were based on Michie et al. (2009)[23] and included three components: low-income population terms (e.g. low-income, poverty, social class or socioeconomic status), terms for the three targeted health behaviours (e.g. physical activity, diet, smoking cessation, lifestyle, health behaviour, or weight reduction) and intervention-relevant terms (e.g. behaviour/behaviour change, health program, intervention, health promotion or program evaluation). The specific strategies were iteratively created and tailored to each database's reference terms with an experienced NHS Clinical Librarian (PM). One author (ERB) initially ran the final searches on 1st December 2011 (Jan 2006 – Dec 2011) and updated the search using the same search terms in the same databases on 10th July 2014 (Dec 2011 – July 2014). In addition to the primary search, we checked the bibliography of each included study.

Study selection

One author (ERB) used the current review's inclusion criteria to screen the full texts of the 13 studies published between 1995 – 2006 included in Michie et al. (2009).[23] For the studies published from 2006 onwards ERB, NM and SUD initially screened titles and abstracts, and obtained potentially relevant studies for full text screening. If no abstract was available the full text was scanned at this first screening stage. If no full text was retrieved, or screening information was missing, ERB contacted the corresponding study author requesting further information. NM and EB double screened a random sample of 10% of titles and abstracts from the studies from 2006 onwards which they had not previously screened (*n*=257), agreement with the primary screener was 96%. Later in the

screening process, NM screened a random sample of 10% of full text articles assessed (*n*=12), agreement was 92%. The small number of disagreements were resolved through discussion.

Data collection process

Data were extracted using a pre-specified and piloted data extraction form based on Davidson et al.'s (2003)[26] criteria, including study design, target behaviour, participants, recruitment strategies, intervention content and outcome data. Risk of bias in individual studies was assessed based on standard criteria adapted from Avenell et al. (2004).[27] Where published supplementary materials were available they were used to assist data extraction (these are referred to in Table 1 online) and if information was missing, the corresponding author was contacted. When interventions targeted more than one behaviour then data were extracted for the different behaviours separately. ERB, SUD, NM and MJ jointly extracted the outcome data.

Data were extracted for all reported time points. The primary outcome was behaviour or behaviour change following the end of the intervention. For the dichotomous smoking outcomes proportions were extracted (e.g. percent of sample reporting smoking abstinence for the last seven days). For continuous diet and physical activity outcomes means and standard deviations were extracted (e.g. mean portions of fruit and vegetables consumed per week). Where there was a choice of outcome measures, the outcome chosen was the primary behavioural outcome measure specified by the authors, measured by the most objective means (e.g. accelerometer data was preferred to self-reported minutes of physical activity) and adjusted for baseline differences if this had been seen as necessary by the authors.

Synthesis of results

Data from included studies were meta-analysed in RevMan (Version 5.2) using random effect models. For outcomes where a reduction (e.g. mean percentage calories in fat) signifies a change in a healthy direction, data were reverse-scored before being entered for meta-analysis. For continuous diet and

physical activity outcomes, standardised mean differences (SMD) were calculated using Hedges' *g*.[28] to express the difference between the means for the intervention and control groups in standard deviation units. For dichotomous smoking outcomes, we calculated relative risk (RR) of smoking abstinence and applied the Cochran-Mantel-Haenszel test.[29]

Where studies had multiple comparisons (several intervention arms or reported outcomes for different behaviours) or were cRCTs, we adjusted participant numbers in line with Cochrane recommendations where possible.[30] We conducted meta-analyses for the three behaviours separately at two time points: the most proximal time point post intervention and the longest follow-up time point where reported. A 95% confidence interval was used and $p<.05$ was taken as significant. We assessed variation in effect size between studies using the I^2 statistic, with an I^2 >50% interpreted as indicating the presence of heterogeneity.[27] Following Cochrane Handbook recommendations[30], we compared independent subgroups of studies differing for two clinically relevant characteristics: interventions targeting women only vs. a mixed sex sample, and interventions targeting a single behaviour vs. multiple behaviours. Publication bias was assessed by visually inspecting funnel plots.

Results

Study selection

A flow diagram is presented in Figure 1. We identified 3939 references from the database search (including the updated search: numbers for this search are given in Figure 1) along with the 13 studies identified in Michie et al.'s (2009)[23] review. After removing 1383 duplicates and excluding 2439 references on the basis of title and abstract screening 130 full texts were screened, of which 120 full texts were successfully retrieved, as eight articles had no full text and two were irretrievable. Full text screening initially led to the inclusion of 32 studies. Three further studies were identified from title screening reference sections, so that 35 studies with 45 comparisons met inclusion criteria[25, 31-71].

---------- Figure 1 here ----------

Study characteristics

Participant identification and recruitment

Studies initially identified low-income participants through their place of residence (i.e. living within an identified deprived area), by belonging to certain ethnic groups identified by the authors as suffering income inequality, being registered on a financial support programme, through belonging to a health clinic serving disadvantaged groups, by their employment (working in a manual workplace) or by an indicator of income (e.g. quintile on the electoral role). Table 1 (supplementary file online) describes how each study defined its study population as 'low-income'. Twenty-three studies reported having measured participants' income as part of the study. Varying thresholds and income groupings were applied, but most commonly, incomes below $15-20,000 USD (£8840-11,800) per year were considered 'low' and most studies reported that the majority of participants were in this category. Of the remaining 12 studies, eight recruited participants from financial support programmes which required beneficiaries' earnings to be equivalent or near to official USA poverty levels (which vary over time and depending on the individual's household size), two reported that the majority of participants held a manual, low wage occupation and the final two studies reported that participants' neighbourhoods had a high proportion of residents living in poverty.

Following initial identification, participants were recruited through face-to-face contact, via letter, telephone, via media advertisement or most commonly a mixture of methods. Face-to-face opportunities described were door-to-door neighbourhood recruitment, organisation of a community health fair, invitation at medical or social services appointments, or through presentations at schools or other community groups. Telephone calls were usually a follow-up method of contact. Media advertisements included posters in community venues, newspaper, radio and television advertisements. In the majority of cases, it was the study investigators who initiated these recruitment activities. Timeframe of recruitment varied from one day to over two years. Techniques used to engage low-income groups in participating were poorly specified: those most commonly reported were offers of material incentives (e.g. vouchers for signing up), prompts and cues (e.g. a fridge

magnet with the study telephone number) or social support to facilitate participation (e.g. advising about crèche facilities).

Study design and participant characteristics

The characteristics of the 35 included studies are summarised in Table 1 (web-only data online). The majority (*k*=30) were conducted in the USA; the remaining studies were from the UK (*k*=3), Australia (*k*=1) and Chile (*k*=1). Twenty-eight studies were RCTs; seven were cRCTs. Studies took place in community (*k*=22), health care (*k*=12) or workplace (*k*=1) settings. Seven studies tested a dietary intervention, seven studies tested a physical activity intervention, 15 studies tested a smoking intervention, and the remaining six tested interventions for multiple behaviours (five tested diet and physical activity interventions, one tested diet and smoking interventions). Three studies had multiple intervention arms for one behaviour. In total, this yielded 16 interventions for the dietary meta-analysis, 12 interventions for physical activity meta-analysis and 17 for smoking meta-analysis. Each study randomised between 27 and 2549 participants, yielding a total of exactly 17,000 participants across the 35 studies. Of the 34 studies specifying participants' sex, 19 targeted women exclusively and no study sampled only men. Women formed 72.4% of all participants. Mean average age of participants was 38.6, this ranged from 22.0 to 66.2 across study subgroups.

Intervention content

The content of interventions varied from provision of tailored self-help materials, to individual counselling or group programmes, but was often complex and poorly described (Table 1 online). Control groups in the intervention tended to receive usual care, a less intense version of the intervention or an inactive version (e.g. non-tailored materials). Intervention duration varied from a single episode to two years; the mode duration was three months. The intervention facilitator was described in 18 studies. In 13 studies this was either a routine healthcare provider such as a nurse or general medical practitioner, or a 'non-routine' healthcare provider such as a psychologist, dietician or smoking counsellor. Of the remaining 5 studies, the facilitator was a peer educator in three studies and a study administrator in two.

Intervention outcomes

Twenty-one studies assessed the behavioural outcome using self-report; 14 studies included an objective measure relating to behaviour such as biochemically-confirmed smoking cessation. For dietary interventions, the primary outcome was fruit and vegetables consumed, grams of fat, dietary risk assessment score (which estimates saturated fat and cholesterol intake) or calories from fat consumed per day. For physical activity, studies reported a wider range of outcomes including mean number of minutes or hours of moderate physical activity per week, metres walked in six minutes, or metabolic equivalent minutes of activity per week. Smoking studies reported the number of participants who were abstinent from smoking, such as for the last seven days, post-partum or for the previous six months. Studies differed in the delay between end of the intervention and most proximal assessment: this ranged from a few hours up to eight months. Fourteen studies included follow-up data beyond the end of intervention time point. Overall 19.8% participants did not complete final assessments.

Risk of bias within studies

Table 2 (web-only data online) details the risk of bias assessment of the included studies. Risk of bias was variable. The majority of studies did not describe random allocation concealment procedures, provided numbers but not reasons for dropouts, did not mention blinding of any party, and stated having used intention-to-treat analyses. There is therefore some risk of bias particularly during randomisation and surrounding blinding.

Quantitative data synthesis: Effectiveness of interventions

Diet

Study outcomes are included in Table 3 (web only data online). The sixteen dietary interventions were found to have an SMD of 0.22 [95% CI 0.14 to 0.29, I^2=48%] (Figure 2). Eight dietary interventions

provided longer-term follow-up data, for 6-12 months post-baseline with combined SMD of 0.16 [95% CI 0.08 to 0.25, I^2=41%].

---------- Figure 2 here ----------

Physical Activity

Twelve physical activity interventions yielded an SMD of 0.21 [95% CI 0.06 to 0.36, I^2=76%] (Figure 3). Three interventions provided longer-term follow-up data 6-8 months post-baseline with a combined SMD of 0.17 [95% CI -0.02 to 0.37, I^2=0%].

Subgroup analyses for heterogeneity suggested SMDs were not different [p=.48] in 4 interventions targeting women only [SMD 0.14, 95% CI 0.00 to 0.27, I^2=0%] compared to 8 with a mixed sex sample [SMD 0.24, 95% CI -0.02 to 0.49, I^2=90%]. Effects were larger [p<.001] in 7 interventions targeting physical activity only [SMD 0.32, 95% CI 0.18 to 0.45, I^2=32%] than 5 interventions targeting multiple behaviours including physical activity [SMD 0.00, 95% CI -0.07 to 0.08, I^2=0%].

---------- Figure 3 here ----------

Smoking

Seventeen smoking interventions were found to have a RR of smoking abstinence of 1.59 [95% CI 1.34 to 1.89, I^2=40%] (Figure 4). Ten interventions provided longer-term follow-up data for 3-12 months post-baseline. Positive intervention effects were not maintained, RR of smoking abstinence was 1.11 [95% CI 0.93 to 1.34, I^2=15%].

---------- Figure 4 here ----------

Publication bias

Visual inspection of funnel plots showed little evidence of publication bias.

Discussion

Summary of Evidence

We systematically reviewed the effectiveness of interventions targeted at changing the diet, physical activity or smoking of low-income groups. The review updates and extends a previous narrative review[23] by including recently published studies; incorporating RCTs only; and applying meta-analysis to examine intervention effect.

We identified 35 studies containing 45 dietary, physical activity and smoking interventions[25, 31-71]. Studies used a wide range of methods to identify and engage low-income participants. Most studies were conducted in the USA, contained mostly women and were often delivered by a healthcare professional. The quality of studies was variable with some risk of bias identified.

Our meta-analysis estimated a post intervention SMD of 0.22 for diet, 0.21 for physical activity interventions and a RR of smoking abstinence of 1.59 for smoking interventions. This means that the interventions had small positive effects on behaviour relative to controls[72]. For studies reporting follow-up data, the small positive effects were maintained for diet (SMD 0.16) but not physical activity (SMD 0.17) or smoking cessation (RR 1.11). However long-term effects are based on a small subset of studies. Our exploration of the variation between physical activity interventions suggested that studies which focussed on a single behaviour were more effective.

Implications of findings

We found small intervention effects on the behaviour of low-income groups compared to controls. For healthy eating, this was equivalent to intervention groups eating just under half a portion of fruit and vegetables more than controls each day. Similar reviews not targeting low-income participants tend to report larger effects: four such reviews targeting adults in the general population[73-75] or obese adults with additional risk factors[76] reported larger effects for diet (SMD 0.31),[75] physical activity (SMD 0.28-0.32)[73,75,76] and smoking (RR 2.17) interventions.[74] Although true comparison is not possible

unless the same interventions were compared in different population groups, this does suggest that interventions may be less effective for low-income populations. If other population groups benefit more from current interventions, even than those specifically targeted at low-income groups, then we can expect an overall gradual widening of health inequalities, as has been reported.[2] Clearly research with more effective interventions is needed, including RCTs conducted in the UK, to increase our understanding of 'what works' for low-income groups.

Our analysis of the variation in physical activity studies showed a trend towards studies being more effective if they target a single behaviour than two behaviours. In addition, only one smoking study targeted both smoking and diet[31,32] and this was the study with the lowest overall effect size. This resonates with the argument that human self-regulation draws on limited resources[77,78] which may be best applied to one behaviour change target at a time. In contrast, physical activity studies including women only did not seem to vary widely in effectiveness from those with a mixed sex sample. Nevertheless there may be other unexplored sources of heterogeneity including other aspects of the delivery of interventions, such as those in the TIDIER checklist[79] or use of techniques from the recently published Behaviour Change Technique taxonomy v1.[80]

Limitations

This study was a systematic but not exhaustive review, for instance not including informally published reports or 'grey literature', which tend not to be indexed within conventional databases. It limited its scope to RCTs and cluster RCTs to gather the highest quality evidence available, but some authors argue that reviewers should include less well-controlled studies because they often have enhanced external validity.[81] In common with similar reviews[82] methodological quality of studies was variable: for example few studies blinded participants, facilitators or outcome assessors to treatment group. However, blinding of treatment condition in behavioural interventions is notoriously difficult: this is a criticism common to many similar reviews.[83]

Definitions of and thresholds for 'low-income' varied somewhat between studies, reflecting the fact that there is no one agreed-upon 'cut-off' for low-income. We specified that the term 'low income' had to be used to refer to participants for studies to be included, since this is a relevant deprivation indicator in our financial and social context, perhaps more so than others such as education level. However, relevant papers not using this term may have been missed, particularly studies from some settings (e.g. perhaps a church setting) where income may have been less likely to have been measured than others (e.g. the workplace). Nevertheless, our review did identify studies using a wide range of concepts to target low socioeconomic status, such as area of residence, belonging to certain ethnic groups, belonging to a health clinic serving disadvantaged groups, as well as concepts directly linked to low income, such as indicator of income. Therefore using the term 'low income' allowed us to implement a clear, objective and replicable criterion for including studies in the review, while also allowing us to capture studies considering low socioeconomic status in a variety of ways.

Additionally, the majority of studies were conducted in the USA, limiting generalisability to the UK context, although effect sizes for the UK studies fell within the typical range. Interventions were generally poorly specified. Categorisation or coding of control group content was not possible, even though studies show that this may vary substantially and influence intervention outcomes.[84] Our review is also limited in scope to studies written in the English language. A final caveat for our findings is that whilst we excluded a study where the authors advised us that the data were zero-inflated[85] this may have been true of other studies.

Conclusions

This systematic review with meta-analysis of randomised controlled interventions to improve the diet, physical activity or smoking behaviour of low-income groups found small positive effects of interventions on behaviour compared to controls, which persisted over time only for diet. Despite research highlighting the urgent need for effective behaviour change support for people from low-income groups to assist in reducing health inequalities,[10-12] this review suggests that our current

interventions for low-income groups are positive, but small, risking 'intervention-generated inequalities'.[22] Policy makers and practitioners alike should seek improved interventions for disadvantaged populations to change health behaviours in the most vulnerable people and reduce health inequalities.

What this paper adds

What is already known on this subject

- Low-income groups in the UK and elsewhere face substantial health inequalities compared to middle and high-income groups, in part caused by differences in diet, physical activity and smoking behaviours.
- There has been no quantitative evidence synthesis of whether interventions targeted at low-income groups in health, workplace and community settings are effective in changing diet, physical activity and smoking behaviours.

What this study adds

- Our meta-analysis of 35 Randomised Controlled Trials suggests that interventions in low-income groups tend to have small positive effects on dietary behaviour, physical activity and smoking compared to controls. These effects were maintained over the longer term for diet only
- Physical activity and smoking interventions were more likely to be effective if they focussed on helping people to change one behaviour at a time.
- The effects of behaviour change interventions in low-income groups are smaller than those reported for interventions in other population samples. Differential effectiveness across the socioeconomic spectrum may exacerbate health inequalities.

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Competing interest declaration

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available from the corresponding author) and we declare that none of the authors have competing interests to disclose. No authors have received support from any organisation for the submitted work, have financial relationships with any organisations that might have an interest in the submitted work in the previous years, or other relationships or activities that could appear to have influenced the submitted work

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Contributors

ERB and MJ had the original idea for the paper and designed the review method and analyses. PM assisted in design of search strategies. ERB, SUD, NM and MJ participated in study selection and data extraction. ERB and SUD conducted statistical analysis. ERB, SUD, NM and MJ participated in writing the manuscript. ERB is the guarantor for the study.

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Independence of authors

The views expressed in this paper are those of the authors

Transparency declaration

The lead author (ERB) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Ethical approval

Not required

Data sharing

Additional data are published in supplementary files.

Figure Legends

Figure 1: Study selection flow diagram *(italics signify numbers from July 2014 updated search)*

Figure 2: Standardised Mean Differences immediately post intervention for studies focusing on dietary change (ordered by effect size)

Figure 3: Standardised Mean Differences immediately post intervention for studies focusing on physical activity change, (ordered by effect size)

Figure 4: Relative Risk of smoking abstinence immediately post intervention for studies focusing on smoking interventions (ordered by effect size)

Supplementary Online materials (web-only data)

- **Supplementary file 1:** Example Search Strategy
- **Table 1:** Study Characteristics
- **Table 2:** Risk of bias
- **Table 3:** Study Outcomes
- **Supplementary file 5:** BMJ reviewer comments and response

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Are interventions for low-income groups effective in changing healthy eating, physical activity and smoking behaviours? A systematic review and meta-analysis

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Abstract

Background: Individuals can positively impact health and longevity by changing health-related behaviours, including diet, smoking and physical activity. Health outcomes and behaviours are unevenly distributed: people with lower socio-economic status, such as those with a low income, are less likely to engage in positive health behaviours and experience good health. No systematic review with meta-analysis has examined randomised controlled trial (RCT) evidence of the effectiveness of behaviour change interventions for low-income groups.

Objective: Examine RCTs and Cluster RCTs of behavioural interventions targeting diet, physical activity or smoking in low-income adults.

Design: Systematic review with random effects meta-analyses. Studies before 2006 were identified from a previously published systematic review (searching 1995-2006) with similar but broader inclusion criteria (including non-randomised controlled trials). Studies from 2006-2014 were identified from eight electronic databases using a similar search strategy.

Data sources: Medline, Embase, PsycINFO, ASSIA, CINAHL, Cochrane Controlled Trials, Cochrane Systematic Review and DARE.

Eligibility criteria for selecting studies: RCTs published from 1995-2014; interventions targeting dietary, physical activity and smoking; low-income adults; reporting of behavioural outcomes.

Main outcome measures: Dietary, physical activity and smoking cessation behaviours.

Results: 35 studies containing 45 interventions with 17,000 participants met inclusion criteria. At post-intervention, effects were positive but small for diet [Standardised Mean Difference (SMD) 0.22, 95%CI 0.14 to 0.29], physical activity [SMD 0.21, 95%CI 0.06 to 0.36] and smoking [relative risk

(RR) of 1.59, 95%CI 1.34 to 1.89]. Studies reporting follow-up results suggested that effects were maintained over time for diet [SMD 0.16, 95%CI 0.08 to 0.25] but not physical activity [SMD 0.17, 95%CI -0.02 to 0.37] or smoking [RR 1.11, 95%CI 0.93 to 1.34].

Conclusions: Behaviour change interventions for low-income groups had small positive effects on healthy eating, physical activity and smoking. Further work is needed to improve the effectiveness of behaviour change interventions for deprived populations.

Article Summary

Strengths and limitations of the study

- This was a comprehensive systematic review with meta-analysis to examine the effects of behavioural interventions in a deprived proportion of the population, namely those with a low income.
- We updated a previous review on this topic and focussed exclusively on evidence from RCTs, which are often termed 'the golden standard' of research.
- Applying meta-analysis enabled us to summarise the data quantitatively and estimate pooled effect sizes, which could be compared to those for interventions from other population groups.
- We searched for studies where participants were described as 'low-income' as this is a financially and socially relevant indicator of deprivation, but relevant papers not using this term may have been missed
- We searched for studies using a range of databases, but we may have missed relevant studies not indexed within the 'grey literature'.
- The majority of the studies were conducted in the USA, potentially limiting generalisability and did not tend to describe their intervention content comprehensively, making it difficult to further explore 'what works' for people with a low income.

Introduction

Health outcomes are strongly correlated with social position in societies across the western world: individuals from deprived backgrounds die younger and experience a greater proportion of their lives with a disability.[1-5] In the most deprived areas of England, for example, life expectancy is approximately eight years less, and disability-free life expectancy 15 years less than in the least deprived areas.[1] Amongst several deprivation indicators, a person's individual or household income is widely recognised as being strongly positively correlated with health outcomes[3]. The social gradient in health is predicted to steepen further[2] despite policy efforts aimed at maximising equality.[3-5]

Behaviours linked to health, particularly healthy eating, physical activity and smoking, show a similar social gradient to health outcomes. Consumption of tobacco, a poor diet and a lack of physical activity are major risks to premature morbidity and mortality.[6,7] People of lower socioeconomic status are more likely to smoke,[5] be sedentary[8] and eat a poor diet[9] compared to those of higher socioeconomic status. These behaviours have been suggested as mediators of the link between social position and health outcomes.[10-12]

Changing health behaviours

Given the potential improvements that changes in behaviour can bring to health, health research and clinical practice devotes considerable time and effort to behavioural interventions. For instance, stopping smoking increases life expectancy at any age and halves the risk of cardiovascular disease within one year.[13] Experts agree that major improvements in public health will be brought about through behaviour changes in the population.[7,14,15] Targeting behaviour change efforts at people at the lower end of the income spectrum is seen as a major means to reducing health inequalities. Gruer et al. (2009) [12 (p. 5)] for instance argued that 'the scope for reducing health inequalities related to social position […] is limited unless many smokers in lower social positions can be enabled to stop smoking.'

Health behaviour change in low-income populations

Existing behaviour change support for those disadvantaged by income may not be fit for purpose.[14] Evidence suggests that people from low-income groups are more difficult to identify and successfully recruit to general population interventions.[16-18] Moreover, it has been suggested that low-income populations may achieve poorer behaviour change outcomes following interventions compared to more affluent participants, resulting in poorer health outcomes[19-21] and potentially leading to intervention-generated inequalities.[22]

In studies targeted at the whole population rather than specific subgroups, Michie et al. (2009)[23] have argued that observed differences in outcomes between socio-economic groups may reflect baseline differences in health behaviours, and that the interventions themselves may be effective across the socio-economic spectrum. In their review of interventions targeted specifically at those disadvantaged by income, examining controlled studies (with or without random allocation) published between 1995 and 2006, they found 13 relevant studies with 17 available comparisons. Approximately half of interventions were reported as effective relative to controls, but no meta-analysis was performed to estimate an overall effect size. At present, there is a lack of evidence on the effectiveness of interventions specifically targeting health behaviour change in low-income individuals.[24,25]

The aim of the current systematic review is to build on Michie et al.'s (2009)[23] work by (a) providing an updated review including studies published since 2006, (b) including only randomised controlled trials and (c) applying meta-analysis to estimate intervention effect sizes. We investigated whether studies of interventions targeted at participants from low-income groups are effective in changing diet, physical activity or smoking behaviour.

Methods

Eligibility criteria

A protocol for this review is not publicly available, however this article does reflect the relevant components of the PRISMA checklist for the reporting of systematic reviews. The article was submitted with a copy of the checklist confirming this.

Studies included in this review had to meet the following inclusion criteria:

- **Population:** *Adults aged 18 years and over, of low-income and from the general population.* Studies were considered to target a low-income group if they explicitly referred to their participants as 'low-income'. General population was defined as not belonging to a specific clinical group, such as those with diabetes or cardiovascular disease. Pregnant and overweight individuals were not considered to belong to a clinical group and were therefore included.
- **Interventions:** *Interventions targeting a change in smoking, eating and/or physical activity behaviours.* Studies could target a single behaviour or multiple behaviours in any combination.
- **Study design:** *Published Randomised Controlled Trials (RCTs) and Cluster Randomised Controlled Trials (cRCTs).* Control condition could be no intervention, a less intense intervention or an intervention with different content.
- **Outcomes***: Behavioural outcomes relevant to smoking cessation, healthy eating and physical activity without no restrictions on length of follow-up.* Self-reported individual-level behaviour, more 'objective' measures of behaviour and measures of behavioural change were all included, as in Michie et al. (2009).[23] Studies were excluded if reported data were unsuitable for meta-analysis.
- **Date:** *1995-2014:* Studies published from 1995-2006 were identified by screening Michie et al. (2009)[23], the primary search included studies published between January 2006 and July 2014 ~~was conducted from 2006 to end of 2011 We~~ . We chose to focus on studies published within the previous two decades to ensure relevance to current financial, social, health and healthcare climates.
- **Language:** *English language:* in line with Michie et al. (2009)'s review. [23]

Search strategy

We used studies from 1995-2006 which had been identified by Michie et al's (2009) review rather than running the search again because the previous review's search criteria were similar but broader than our own and should therefore include all articles relevant to the current review. Specific search strategies were created (see supplementary file 1, web-only data online) to search for studies published since Michie et al.'s (2009)[23] review of 1995-2006 papers. We searched eight databases: Medline, Embase, PsycINFO, ASSIA, CINAHL, Cochrane Controlled Trials, Cochrane Systematic Reviews and DARE Electronic Databases. Search strategies were based on Michie et al. (2009)[23] and included three components: low-income population terms (e.g. low-income, poverty, social class or socioeconomic status), terms for the three targeted health behaviours (e.g. physical activity, diet, smoking cessation, lifestyle, health behaviour, or weight reduction) and intervention-relevant terms (e.g. behaviour/behaviour change, health program, intervention, health promotion or program evaluation). The specific strategies were iteratively created and tailored to each database's reference terms with an experienced NHS Clinical Librarian (PM). One author (ERB) initially ran the final searches on 1st December 2011 (Jan 2006 – Dec 2011) and updated the search using the same search terms in the same databases on 10th July 2014 (Dec 2011 – July 2014). In addition to the primary search, we checked the bibliography of each included study.

Study selection

One author (ERB) used the current review's inclusion criteria to screen the full texts of the 13 studies published between 1995 – 2006 included in Michie et al. (2009).[23] For the studies published from 2006 onwards ERB, NM and SUD initially screened titles and abstracts, and obtained potentially relevant studies for full text screening. If no abstract was available the full text was scanned at this first screening stage. If no full text was retrieved, or screening information was missing, ERB contacted the corresponding study author requesting further information. NM and EB double screened a random sample of 10% of titles and abstracts from the studies from 2006 onwards which they had not previously screened (*n*=257), agreement with the primary screener was 96%. Later in the

screening process, NM screened a random sample of 10% of full text articles assessed (*n*=12), agreement was 92%. The small number of disagreements were resolved through discussion.

Data collection process

Data were extracted using a pre-specified and piloted data extraction form based on Davidson et al.'s (2003)[26] criteria, including study design, target behaviour, participants, recruitment strategies, intervention content and outcome data. Risk of bias in individual studies was assessed based on standard criteria adapted from Avenell et al. (2004).[27] Where published supplementary materials were available they were used to assist data extraction (these are referred to in Table 1 online) and if information was missing, the corresponding author was contacted. When interventions targeted more than one behaviour then data were extracted for the different behaviours separately. ERB, SUD, NM and MJ jointly extracted the outcome data.

Data were extracted for all reported time points. The primary outcome was behaviour or behaviour change following the end of the intervention. For the dichotomous smoking outcomes proportions were extracted (e.g. percent of sample reporting smoking abstinence for the last seven days). For continuous diet and physical activity outcomes means and standard deviations were extracted (e.g. mean portions of fruit and vegetables consumed per week). Where there was a choice of outcome measures, the outcome chosen was the primary behavioural outcome measure specified by the authors, measured by the most objective means (e.g. accelerometer data was preferred to self-reported minutes of physical activity) and adjusted for baseline differences if this had been seen as necessary by the authors.

Synthesis of results

Data from included studies were meta-analysed in RevMan (Version 5.2) using random effect models. For outcomes where a reduction (e.g. mean percentage calories in fat) signifies a change in a healthy direction, data were reverse-scored before being entered for meta-analysis. For continuous diet and

physical activity outcomes, standardised mean differences (SMD) were calculated using Hedges' *g*.[28] to express the difference between the means for the intervention and control groups in standard deviation units. For dichotomous smoking outcomes, we calculated relative risk (RR) of smoking abstinence and applied the Cochran-Mantel-Haenszel test.[29]

Where studies had multiple comparisons (several intervention arms or reported outcomes for different behaviours) or were cRCTs, we adjusted participant numbers in line with Cochrane recommendations where possible.[30] We conducted meta-analyses for the three behaviours separately at two time points: the most proximal time point post intervention and the longest follow-up time point where reported. A 95% confidence interval was used and $p<.05$ was taken as significant. We assessed variation in effect size~~)~~ between studies ~~Degree of inconsistency between studies was assessed~~ using the I^2 statistic, with an I^2 >50% interpreted as ~~considered to signify~~indicating the presence of heterogeneity.[27] ~~This heterogeneity was explored by comparing~~ Following Cochrane Handbook recommendations[30], we compared independent subgroups of studies differing for two clinically relevant characteristics: interventions targeting women only vs. a mixed sex sample, and interventions targeting a single behaviour vs. multiple behaviours. Publication bias was assessed by visually inspecting funnel plots.

Results

Study selection

A flow diagram is presented in Figure 1. We identified 3939 references from the database search (including the updated search:– numbers for this search are given in Figure 1) along with the 13 studies identified in Michie et al.'s (2009)[23] review. After removing 1383 duplicates and excluding 2439 references on the basis of title and abstract screening 130 full texts were screened, of which 120 full texts were successfully retrieved, as eight articles had no full text and two w~~a~~ere~~s~~ irretrievable. Full text screening initially led to the inclusion of 32 studies. Three further studies were identified from title screening reference sections, so that 35 studies with 45 comparisons met inclusion criteria.

---------- Figure 1 here ----------

Study characteristics

Participant identification and recruitment

Studies initially identified low-income participants through their place of residence (i.e. living within an identified deprived area), by belonging to certain ethnic groups identified by the authors as suffering income inequality, being registered on a financial support programme, through belonging to a health clinic serving disadvantaged groups, by their employment (working in a manual workplace) or by an indicator of income (e.g. quintile on the electoral role). Table 1 (supplementary file online) describes how each study defined its study population as 'low-income'. Twenty-three studies reported having measured participants' income as part of the study. Varying thresholds and income groupings were applied, but most commonly, incomes below $15-20,000 USD (£8840-11,800) per year were considered 'low' and most studies reported that the majority of participants were in this category. Of the remaining 12 studies, eight recruited participants from financial support programmes which required beneficiaries' earnings to be equivalent or near to official USA poverty levels (which vary over time and depending on the individual's household size), two reported that the majority of participants held a manual, low wage occupation and the final two studies reported that participants' neighbourhoods had a high proportion of residents living in poverty.

Following initial identification, participants were recruited through face-to-face contact, via letter, telephone, via media advertisement or most commonly a mixture of methods. Face-to-face opportunities described were door-to-door neighbourhood recruitment, organisation of a community health fair, invitation at medical or social services appointments, or through presentations at schools or other community groups. Telephone calls were usually a follow-up method of contact. Media advertisements included posters in community venues, newspaper, radio and television advertisements. In the majority of cases, it was the study investigators who initiated these recruitment activities. Timeframe of recruitment varied from one day to over two years. Techniques used to engage low-income groups in participating were poorly specified: those most commonly reported were offers of material incentives (e.g. vouchers for signing up), prompts and cues (e.g. a fridge

magnet with the study telephone number) or social support to facilitate participation (e.g. advising about crèche facilities).

Study design and participant characteristics

The characteristics of the 35 included studies are summarised in Table 1 (web-only data online). The majority (*k*=30) were conducted in the USA; the remaining studies were from the UK (*k*=3), Australia (*k*=1) and Chile (*k*=1). Twenty-eight studies were RCTs; seven were cRCTs. Studies took place in community (*k*=22), health care (*k*=12) or workplace (*k*=1) settings. Seven studies tested a dietary intervention, seven studies tested a physical activity intervention, 15 studies tested a smoking intervention, and the remaining six tested interventions for multiple behaviours (five tested diet and physical activity interventions, one tested diet and smoking interventions). Three studies had multiple intervention arms for one behaviour. In total, this yielded 16 interventions for the dietary meta-analysis, 12 interventions for physical activity meta-analysis and 17 for smoking meta-analysis. Each study randomised between 27 and 2549 participants, yielding a total of exactly 17,000 participants across the 35 studies. Of the 34 studies specifying participants' sex, 19 targeted women exclusively and no study sampled only men. Women formed 72.4% of all participants. Mean average age of participants was 38.6, this ranged from 22.0 to 66.2 across study subgroups.

Intervention content

The content of interventions varied from provision of tailored self-help materials, to individual counselling or group programmes, but was often complex and poorly described (Table 1 online). Control groups in the intervention tended to receive usual care, a less intense version of the intervention or an inactive version (e.g. non-tailored materials). Intervention duration varied from a single episode to two years; the mode duration was three months. The intervention facilitator was described in 18 studies. In 13 studies this was either a routine healthcare provider such as a nurse or general medical practitioner, or a 'non-routine' healthcare provider such as a psychologist, dietician or smoking counsellor. Of the remaining 5 studies, the facilitator was a peer educator in three studies and a study administrator in two.

Intervention outcomes

Twenty-one studies assessed the behavioural outcome using self-report; 14 studies included an objective measure relating to behaviour such as biochemically-confirmed smoking cessation. For dietary interventions, the primary outcome was fruit and vegetables consumed, grams of fat, dietary risk assessment score (which estimates saturated fat and cholesterol intake) or calories from fat consumed per day. For physical activity, studies reported a wider range of outcomes including mean number of minutes or hours of moderate physical activity per week, metres walked in six minutes, or metabolic equivalent minutes of activity per week. Smoking studies reported the number of participants who were abstinent from smoking, such as for the last seven days, post-partum or for the previous six months. Studies differed in the delay between end of the intervention and most proximal assessment: this ranged from a few hours up to eight months. Fourteen studies included follow-up data beyond the end of intervention time point. Overall 19.8% participants did not complete final assessments.

Risk of bias within studies

Table 2 (web-only data online) details the risk of bias assessment of the included studies. Risk of bias was variable. The majority of studies did not describe random allocation concealment procedures, provided numbers but not reasons for dropouts, did not mention blinding of any party, and stated having used intention-to-treat analyses. There is therefore some risk of bias particularly during randomisation and surrounding blinding.

Quantitative data synthesis: Effectiveness of interventions

Diet

Study outcomes are included in Table 3 (web only data online). The sixteen dietary interventions were found to have an SMD of 0.22 [95% CI 0.14 to 0.29, I^2=48%] (Figure 2). Eight dietary interventions

provided longer-term follow-up data, for 6-12 months post-baseline with combined SMD of 0.16 [95% CI 0.08 to 0.25, I^2=41%].

---------- Figure 2 here ----------

Physical Activity

Twelve physical activity interventions yielded an SMD of 0.21 [95% CI 0.06 to 0.36, I^2=76%] (Figure 3). Three interventions provided longer-term follow-up data 6-8 months post-baseline with a combined SMD of 0.17 [95% CI -0.02 to 0.37, I^2=0%].

Subgroup analyses for heterogeneity suggested SMDs were not different [p=.48] in 4 interventions targeting women only [SMD 0.14, 95% CI -0.00 to 0.27, I^2=0%] compared to 8 with a mixed sex sample [SMD 0.24, 95% CI -0.02 to 0.49, I^2=90%]. Effects were larger [p<.001] in 7 interventions targeting physical activity only [SMD 0.32, 95% CI 0.18 to 0.45, I^2=32%] than 5 interventions targeting multiple behaviours including physical activity [SMD 0.00, 95% CI -0.07 to 0.08, I^2=0%].

---------- Figure 3 here ----------

Smoking

Seventeen smoking interventions were found to have a RR of smoking abstinence of 1.59 [95% CI 1.34 to 1.89, I^2=40%] (Figure 4). Ten interventions provided longer-term follow-up data for 3-12 months post-baseline. Positive intervention effects were not maintained, RR of smoking abstinence was 1.11 [95% CI 0.93 to 1.34, I^2=15%].

---------- Figure 4 here ----------

Publication bias

Visual inspection of funnel plots showed little evidence of publication bias.

Discussion

Summary of Evidence

We systematically reviewed the effectiveness of interventions targeted at changing the diet, physical activity or smoking of low-income groups. The review updates and extends a previous narrative review[23] by including recently published studies; incorporating RCTs only; and applying meta-analysis to examine intervention effect.

We identified 35 studies containing 45 dietary, physical activity and smoking interventions. Studies used a wide range of methods to identify and engage low-income participants. Most studies were conducted in the USA, contained mostly women and were often delivered by a healthcare professional. The quality of studies was variable with some risk of bias identified.

Our meta-analysis estimated a post intervention SMD of 0.22 for diet, 0.21 for physical activity interventions and a RR of smoking abstinence of 1.59 for smoking interventions. ~~According to Cohen's effect size conventions,[31]~~ This means that the interventions had small positive effects on behaviour relative to controls[31]. For studies reporting follow-up data, the small positive effects were maintained for diet (SMD 0.16) but not physical activity (SMD 0.17) or smoking cessation (RR 1.11). However long-term effects are based on a small subset of studies. Our exploration of the ~~heterogeneity~~ variation between~~in~~ physical activity ~~and smoking~~ interventions suggested that ~~larger effect sizes in~~ studies which focussed on a single behaviour were more effective.

Implications of findings

We found small intervention effects on the behaviour of low-income groups compared to controls~~:~~ ~~in the~~For healthy eating, this was equivalent to intervention groups eating just under half a portion of fruit and vegetables more than controls each day ~~dietary domain, this was equivalent to just under half a portion of fruit or vegetables per day difference~~. Similar reviews not targeting low-income participants tend to report larger effects: four such reviews targeting adults in the general population[32-

[34] or obese adults with additional risk factors[35] reported larger effects for diet (SMD 0.31),[34] physical activity (SMD 0.28-0.32)[32,34,35] and smoking (RR 2.17) interventions.[33] Although true comparison is not possible unless the same interventions were compared in different population groups, this does suggest that ~~the effects of interventions may be smaller for low-income populations~~interventions may be less effective for low-income populations. If other population groups benefit more from current interventions, even than those specifically targeted at low-income groups, then we can expect an overall gradual widening of health inequalities, as has been reported.[2] Clearly research with more effective interventions is needed, including RCTs conducted in the UK, to increase our understanding of 'what works' for low-income groups.

~~Exploration of heterogeneity~~Our analysis of the variation in physical activity studies showed a trend towards studies being more effective if they target a single behaviour than two behaviours. ~~In the smoking domain only one~~In addition, only one smoking study targeted both smoking and diet[36] and this was the study with the lowest overall effect size. This resonates with the argument that human self-regulation draws on limited resources[37,38] which may be best applied to one behaviour change target at a time. In contrast, physical activity studies including women only did not seem to vary widely in effectiveness from those with a mixed sex sample. Nevertheless there may be other unexplored sources of heterogeneity including other aspects of the delivery of interventions, such as those in the TIDIER checklist[39] or use of techniques from the recently published Behaviour Change Technique taxonomy v1.[40]

Limitations

This study was a systematic but not exhaustive review, for instance not including informally published reports or 'grey literature', which tend not to be indexed within conventional databases. It limited its scope to RCTs and cluster RCTs to gather the highest quality evidence available, but some authors argue that reviewers should include less well-controlled studies because they often have ~~the gains from~~ enhanced external validity ~~in less well-controlled studies such as community-based~~

~~interventions should not be ignored~~.[41] In common with similar reviews[42] methodological quality of studies was variable: for example few studies blinded participants, facilitators or outcome assessors to treatment group. However, blinding of treatment condition in behavioural interventions is notoriously difficult: this is a criticism common to many similar reviews.[43]

Definitions of and thresholds for 'low-income' varied somewhat between studies, reflecting the fact that there is no one agreed-upon 'cut-off' for low-income. We specified that the term 'low income' had to be used to refer to participants for studies to be included, since this is a relevant deprivation indicator in our financial and social context, perhaps more so than others such as education level. However, relevant papers not using this term may have been missed~~,~~, particularly studies from some settings (e.g. perhaps a church setting) where income may have been less likely to have been measured than others (e.g. the workplace). Nevertheless, our review did identify studies using a wide range of concepts to target low socioeconomic status, such as area of residence, belonging to certain ethnic groups, belonging to a health clinic serving disadvantaged groups, as well as concepts directly linked to low income, such as indicator of income. Therefore using the term 'low income' allowed us to implement a clear, objective and replicable criterion for including studies in the review, while also allowing us to capture studies considering low socioeconomic status in a variety of ways.

~~The~~ Additionally, the majority of studies were conducted in the USA, limiting generalisability to the UK context, although effect sizes for the UK studies ~~were not amongst the largest or smallest suggesting they followed the general trends~~fell within the typical range. ~~The intervention and control conditions~~ Interventions were generally poorly specified. Categorisation or coding of control group content was not possible, even though studies show that this may vary substantially and influence intervention outcomes.[44] Our review is also limited in scope to studies written in the English language. A final caveat for our findings is that whilst we excluded a study where the authors advised us that the data were zero-inflated[45] this may have been true of other studies.

Conclusions

This systematic review with meta-analysis of randomised controlled interventions to improve the diet, physical activity or smoking behaviour of low-income groups found small positive effects of interventions on behaviour compared to controls, which persisted over time only for diet. Despite research highlighting the urgent need for effective behaviour change support for people from low-income groups to assist in reducing health inequalities,[10-12] this review suggests that our current interventions for low-income groups are positive, but small, risking 'intervention-generated inequalities'.[22] Policy makers and practitioners alike should seek improved interventions for disadvantaged populations to change health behaviours in the most vulnerable people and reduce health inequalities.

What this paper adds

What is already known on this subject

- Low-income groups in the UK and elsewhere face substantial health inequalities compared to middle and high-income groups, in part caused by differences in diet, physical activity and smoking behaviours.
- There has been no quantitative evidence synthesis of whether interventions targeted at low-income groups in health, workplace and community settings are effective in changing diet, physical activity and smoking behaviours.

What this study adds

- Our meta-analysis of 35 Randomised Controlled Trials suggests that interventions in low-income groups tend to have small positive effects on dietary behaviour, physical activity and smoking compared to controls. These effects were maintained over the longer term for diet only
- Physical activity and smoking interventions were more likely to be effective if they

focussed on helping people to change one behaviour at a time.

- The effects of behaviour change interventions in low-income groups are smaller than those reported for interventions in other population samples. Differential effectiveness across the socioeconomic spectrum may exacerbate health inequalities.

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Competing interest declaration

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available from the corresponding author) and we declare that none of the authors have competing interests to disclose. No authors have received support from any organisation for the submitted work, have financial relationships with any organisations that might have an interest in the submitted work in the previous years, or other relationships or activities that could appear to have influenced the submitted work

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Contributors

ERB and MJ had the original idea for the paper and designed the review method and analyses. PM assisted in design of search strategies. ERB, SUD, NM and MJ participated in study selection and data extraction. ERB and SUD conducted statistical analysis. ERB, SUD, NM and MJ participated in writing the manuscript. ERB is the guarantor for the study.

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Independence of authors

The views expressed in this paper are those of the authors

Transparency declaration

The lead author (ERB) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Ethical approval

Not required

Data sharing

Additional data are published in supplementary files.

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(83) Sykes CM, Marks DF. Effectiveness of a cognitive behaviour therapy self-help programme for smokers in London, UK. Health Promotion Int 2001; **16**:255-60.

(84) Volpp KG, Gurmankin Levy A, Asch DA, Berlin JA, Murphy JJ, Gomez A et al. A randomized controlled trial of financial incentives for smoking cessation. Cancer Epidemiol Biomarkers Prev 2006;**15**(1):12-18.

(85) Wu D, Ma GX, Zhou K, Zhou D, Liu A, Poon AN. The effect of a culturally tailored smoking cessation for chinese american smokers. Nicotine Tob Res 2009; **11**(12): 1448-1457.

Figures

Figure 1: Study selection flow diagram *(italics signify numbers from July 2014 updated search)*

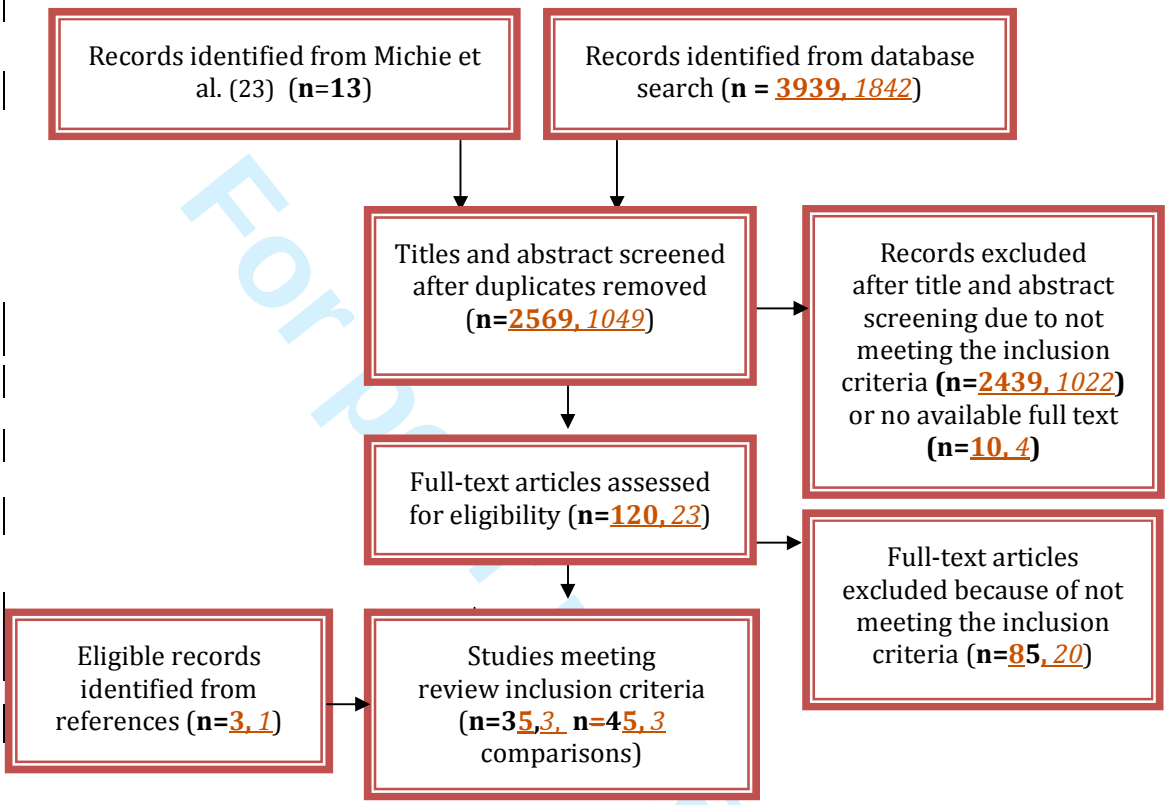
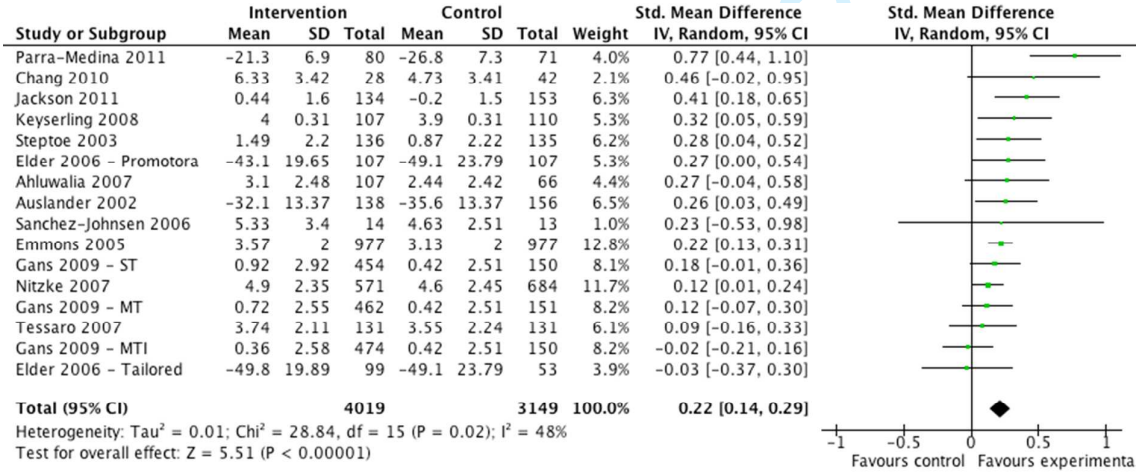


Figure 2: Standardised Mean Differences immediately post intervention for studies focusing on dietary change (ordered by effect size)



Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Parra-Medina 2011	-21.3	6.9	80	-26.8	7.3	71	4.0%	0.77 [0.44, 1.10]
Chang 2010	6.33	3.42	28	4.73	3.41	42	2.1%	0.46 [-0.02, 0.95]
Jackson 2011	0.44	1.6	134	-0.2	1.5	153	6.3%	0.41 [0.18, 0.65]
Keyserling 2008	4	0.31	107	3.9	0.31	110	5.3%	0.32 [0.05, 0.59]
Steptoe 2003	1.49	2.2	136	0.87	2.22	135	6.2%	0.28 [0.04, 0.52]
Elder 2006 - Promotora	-43.1	19.65	107	-49.1	23.79	107	5.3%	0.27 [0.00, 0.54]
Ahluwalia 2007	3.1	2.48	107	2.44	2.42	66	4.4%	0.27 [-0.04, 0.58]
Auslander 2002	-32.1	13.37	138	-35.6	13.37	156	6.5%	0.26 [0.03, 0.49]
Sanchez-Johnsen 2006	5.33	3.4	14	4.63	2.51	13	1.0%	0.23 [-0.53, 0.98]
Emmons 2005	3.57	2	977	3.13	2	977	12.8%	0.22 [0.13, 0.31]
Gans 2009 - ST	0.92	2.92	454	0.42	2.51	150	8.1%	0.18 [-0.01, 0.36]
Nitzke 2007	4.9	2.35	571	4.6	2.45	684	11.7%	0.12 [0.01, 0.24]
Gans 2009 - MT	0.72	2.55	462	0.42	2.51	151	8.2%	0.12 [-0.07, 0.30]
Tessaro 2007	3.74	2.11	131	3.55	2.24	131	6.1%	0.09 [-0.16, 0.33]
Gans 2009 - MTI	0.36	2.58	474	0.42	2.51	150	8.2%	-0.02 [-0.21, 0.16]
Elder 2006 - Tailored	-49.8	19.89	99	-49.1	23.79	53	3.9%	-0.03 [-0.37, 0.30]
Total (95% CI)			4019			3149	100.0%	0.22 [0.14, 0.29]

Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 28.84$, df = 15 (P = 0.02); $I^2 = 48\%$
Test for overall effect: Z = 5.51 (P < 0.00001)

Figure 3: Standardised Mean Differences immediately post intervention for studies focusing on physical activity change, (ordered by effect size)

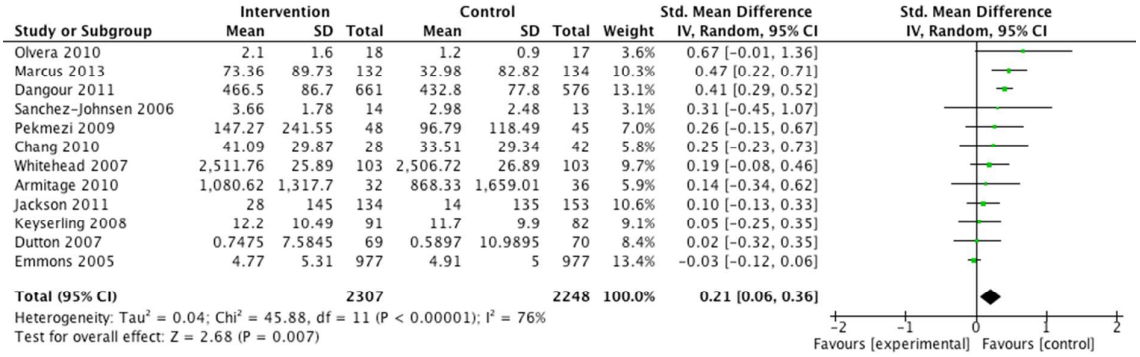
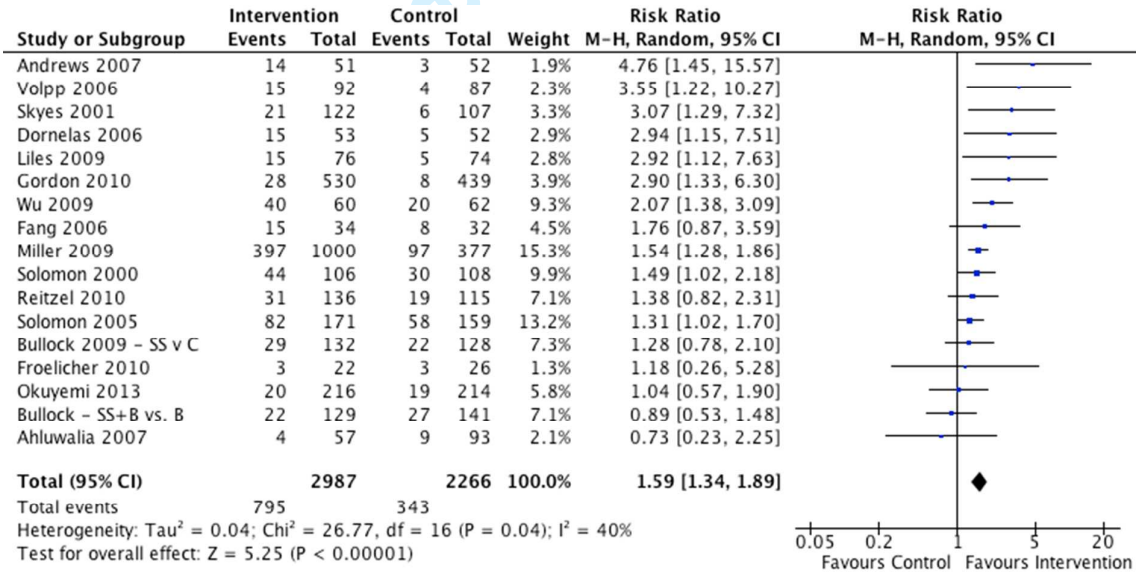


Figure 4: Relative Risk of smoking abstinence immediately post intervention for studies focusing on smoking interventions (ordered by effect size)



Supplementary Online materials (web-only data)

- **Supplementary file 1:** Example Search Strategy
- **Table 1:** Study Characteristics
- **Table 2:** Risk of bias
- **Table 3:** Study Outcomes
- **Supplementary file 5:** BMJ reviewer comments and responses

Supplementary File 1: Example Search Strategy

	Medline Database 1st December 2011	
1	exp poverty/	18153
2	exp poverty areas/	2800
3	exp social class/	15096
4	exp social conditions/	3188
5	"low income".ti,ab.	10169
6	1 or 2 or 3 or 4 or 5	40230
7	exp Life Style/	37377
8	exp weight gain/	14266
9	exp overweight/	77138
10	exp Weight Loss/	17681
11	exp obesity/	75542
12	exp food habits/	10789
13	exp fruit/	32639
14	exp vegetables/	47553
15	exp exercise/	45754
16	exp diet therapy/	16335
17	exp diet/	82764
18	exp Smoking/pc, px, th [Prevention & Control, Psychology, Therapy]	13314
19	exp smoking cessation/	14366
20	exp "Tobacco Use Cessation"/	14858
21	exp "Tobacco Use Disorder"/	5420
22	exp health behavior/	58129
23	"health behavio*".ti,ab.	6627
24	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23	
25	exp program development/	16327
26	exp program evaluation/	40639
27	exp intervention studies/	4265
28	exp health promotion/	32938
29	25 or 26 or 27 or 28	83647
30	6 and 24 and 29	728
31	limit 30 to (english language and yr="2006 -Current")	425

Table 1: Study characteristics: organised by behavioural target and then by alphabetical order of lead study author

Study ID, additional references, year and country of publication	Study design	Participants randomised ▪ N randomised and description ▪ Sex ▪ Age ▪ Reason for description of study population as 'low income'	Intervention description	Control description	Primary outcome	Main outcome time point and follow-up (weeks)
DIET						
Ahluwalia (diet)[31] Supplemented by Okuyemi et al. (2007)[32] 2007 USA	cRCT	▪ 173 smokers in a low-income public housing development ▪ 52 m, 121 f ▪ Mean age = 48 (13.1) ▪ 72.9-74.2% had individual income ≤$800/month	Motivational interviewing counselling, provision of fruit and vegetables, a cookbook and educational videos	Motivational interviewing for smoking and nicotine gum (see Ahluwalia smoking)	SR Portions of fruit and vegetables per day, last 7 days	6 months
Auslander[33] 2002 USA	cRCT	▪ 294 low-income overweight African American women ▪ Mean age ranged from 40.2 (8.2) to 41.2 (7.8) ▪ 60-70% below the poverty line (not defined). Mean family income $1,367.8 ±$1,047.0 to $1,619.1 ± $1,206.7/month	Culturally-tailored peer-led dietary change program	No intervention until after final follow-up	SR mean % of calories from fat	Posttest: 3 month post baseline 6 month post baseline follow-up

Chang (diet)[34] Supplemented by Chang et al. 2009[35] 2010 USA	RCT	▪ 129 overweight and obese mothers from WIC sites ▪ Mean age ranged from 25.12 (4.10) - 25.53 (3.94). 18-34. ▪ Income not reported but mothers eligible for the Women, Infants and Children Supplemental Food and Nutrition Program (WIC) so have a household ≤185% of the federal poverty level, which in 2010 was $3677/month for a family of four*	DVD, peer support group and telephone calls	Usual care	SR cups of fruit and veg per day	2 month, 8 month 8 month follow-up
Elder[36] **(2 arms)** 2006 USA	RCT	▪ 257 low-income, Spanish-dominant Latina women ▪ Mean age = 39.71 (9.93) ▪ 53% had an individual income <$2000/month	**Tailored intervention:** Tailored mailed materials **Promotora intervention:** Tailored materials and weekly home visits/telephone support	Non tailored, off the shelf materials	SR Mean grams of fat per day	M2 12 weeks M3 timepoint '6 m post-intervention' M4 timepoint '12m post-intervention'

Emmons (diet)[37] 2005 USA	cRCT	▪ 1954 low-income multi-ethnic adults ▪ 747 m, 1469f ▪ Age range 18-75 ▪ Income not reported but all participants lived in neighbourhoods classed as 'impoverished' (≥20% live below the federal poverty level)	Behavioural counselling, telephone support and mailings	Usual care: Not well specified	SR Fruit and veg servings per day	Endpoint
Gans[38] **(3 arms)** 2009 USA	RCT	▪ 1841 low-income ethnically diverse adults ▪ 275 m, 1566 f ▪ Mean age = 40.4 (12.9), 18-52 ▪ 56.4% individual income <$20,000/year	**Multiple Tailored (MT) intervention:** 4 tailored mailed educational packages +a DVD **Multiple Re-tailored (MTI) intervention:** 4 tailored educational packages based on telephone reassessments + a DVD	Non tailored nutrition information	SR Fruit and veg servings per day	4 month 7 months follow-up

			Single Tailored (ST) intervention: One tailored mailed educational package			
Jackson (diet)[39] 2011 USA	RCT	▪ 321 ethnically diverse low-income pregnant women ▪ Mean age 26.5 (6) ▪ Income not reported, but 85% of women received Medicaid, which in 2011 required pregnant women to have an individual income ≤$1862/month	Counselling via a virtual video-doctor	Usual care: prenatal care appointment	SR fruit and vegetable intake per day	4 weeks
Keyserling (diet)[40] Supplemented by Jilcott et al. (2006)[41] 2008 USA	RCT	▪ 236 low-income women from the WISEWOMAN program ▪ Mean age ranged from 52 (0.64) – 54 (0.66). ▪ Eligible for study if at or below 200% of the federal poverty level. 93-96% of participants had household income ≤$30,000/year	Counselling	Mailed diet and exercise leaflets	End point data: objectively measured fruit and veg intake, via median serum carotenoids (ug/dL) Follow-up data: fruit and vegetable consumption via Dietary Risk Assessment (score range 0-103,	6 month assessment 12 month assessment

					lower=healthier)	
Nitzke[42] Supplemented by Nitzke et al. 2004[43] 2007 USA	RCT	▪ 2024 low-income young adults ▪ 786 m, 1238 f ▪ Mode age 18. Age range 18-24. ▪ 60% had individual income <$800/month	Tailored nutrition materials	Non-tailored materials	SR Fruit and vegetable intake per day	12 months assessment
Parra-Medina[44] 2011 USA	RCT	▪ 226 low-income African American women ▪ Aged 35 and over, mode age range 35-49, mean not specified ▪ 50% had annual income <$20,000	Stage-matched provider counselling and assisted goal setting plus 12 months of telephone counselling and tailored newsletters	Stage-matched provider counselling and assisted goal setting	SR dietary risk assessment score (rated between 0 and 104, where lower scores equal a lower intake of saturated fat and cholesterol)	12 month assessment
Sanchez-Johnsen[45] (diet) 2006 USA	RCT	▪ 27 overweight Latina women ▪ Mean age ranged from 43.2 (6.3) to 44.9 (8.2). 35-65 ▪ 52% family income <$16,000/year	Diet classes	Mailed health education	SR fruit and veg servings per day	6 week assessment
Steptoe[46] 2003 UK	RCT	▪ 271 adults from deprived areas ▪ Sex not specified ▪ Age range: 18-70 ▪ 68% had an individual income ≤£400 ($640) /week	Behavioural counselling sessions, tailored to motivation level	Non-tailored nutrition education counselling	SR fruit and veg servings per day	12 months

Tessaro[47] 2007 USA	RCT	▪ 395 low-income women ▪ Mean age 50.25 ▪ 67% household income <$20,000 /year	Computer-based interactive nutrition intervention	No intervention: waiting list control	SR fruit and veg servings per day	3 months
PHYSICAL ACTIVITY						
Armitage[25] 2010 UK	RCT	▪ 68 manual workers ▪ 35 m, 33 f ▪ Mean age = 27 (12.71) ▪ Income not reported, though all had manual or clerical job roles	Volitional help sheet with implementation intentions	Help sheet without implementation intentions	SR metabolic equivalent minutes exercise per week (MET minutes)	1 month
Chang (Physical activity)[34] Supplemented by Chang et al. 2009[35] 2010 USA	RCT	*See Chang (diet) above for description of the study's participants*	DVD, peer support group and telephone calls	Usual care	SR metabolic equivalent minutes exercise per week (MET minutes)	2 months 8 month follow-up
Dangour[48] Supplemented by Dangour et al. (2007)[49] 2011	cRCT	▪ 1897 older adults registered with health centres in low-middle socioeconomic status municipalities ▪ 656 m, 1346 f	Physical activity program	Educational materials on healthy eating, and information about healthcare	Objectively measured walking capacity: metres walked in six minutes	24 month assessment

Chile		▪ Mean age ranged from 66.1 (0.9) – 66.2 (1.0). 64-67.9 ▪ Income not reported, but all attended health centres where median 9.2% of the population live in poverty (per capita income less than twice the price of a basic basket of food in Chile)		provision		
Dutton[50] 2007 USA	RCT	▪ 158 overweight low-income African American women ▪ Mean age = 41.73 (12.25) ▪ Participants eligible if individual income <$16,000 /year	Tailored weight loss intervention	Usual care	SR hours exercise per week	Post-treatment
Emmons[37] (physical activity) 2005 USA	cRCT	*See Emmons (diet) above for description of the study's participants*	Behavioural counselling and telephone support and mailings	Usual care? Not well specified	Mean hours per week of physical activity	Endpoint
Jackson[39] (Physical activity) 2011 USA	RCT	*See Jackson (diet) above for description of the study's participants*	Counselling via a virtual video-doctor	Usual care: pre-natal care appointment	SR minutes per week of physical activity	4 weeks
Keyserling[40] (Physical activity)	RCT	*See Keyserling (diet) above for description of the study's participants*	Counselling	Mailed leaflets	Objectively measured PA; accelerometer	6 month assessment

Supplemented by Jilcott et al. (2006)[41] 2008 USA					moderate minutes per day	12 months follow-up
Marcus[51] 2013 USA	RCT	▪ 266 inactive Latina women ▪ Mean age 40.67 (9.98) ▪ 54% family income <$20,000 per year	Tailored Spanish-language mailings of physical activity and individualised feedback reports	Spanish-language mailings on other healthy-heart behaviours	SR minutes of moderate to vigorous physical activity per week	6 month post-intervention outcome
Olvera[52] Supplemented by Olvera et al. (2008)[53] 2010 USA	cRCT	▪ 46 low-income Latina mothers ▪ Mean age ranged from 33.3 (4.6) – 38.2 (10.6) ▪ 76% family income <$20,000 /year	Exercise and counselling	Same but 12 not 36 sessions	SR activity level on a scale from 0 (sedentary) to 7 (vigorous)	12 week assessment
Pekmezi[54] 2009 USA	RCT	▪ 93 Underactive Latina women ▪ Mean age = 41.37 (11.18), 18-65 ▪ 75% household income <$30,000 /year	Tailored monthly mailings on physical activity	6 monthly mailings on other topics	SR minutes physical activity per week	6 months
Sanchez-Johnsen[45] (Physical activity) 2006 USA	RCT	*See Sanchez-Johnsen (diet) above for description of the study's participants*	Exercise classes	Mailed health education	SR times engaged in activity designed to improve fitness on a scale from 1 (0 times) to 9 (more than 7	6 week assessment

					times)	
Whitehead[55] 2007 USA	RCT	▪ 206 low-income African Americans ▪ 36 m, 171 f ▪ Average age 50 ▪ 64% household income <$1000 /month	Mailed tailored physical activity information	Mailed non tailored information about a low-sodium diet	SR time spent in physical activities for last 7 days, yielding an estimated caloric expenditure	1 month assessment 6 month assessment follow-up
SMOKING						
Ahluwalia[31] (Smoking) Supplemented by Okuyemi et al. 2007[32] 2007 USA	RCT	▪ 173 smokers in a low-income public housing development ▪ 52 m, 121 f ▪ Mean age = 48 (13.1) ▪ 72.9-74.2% had individual income ≤$800/month	Motivational interviewing counselling for smoking and nicotine replacement therapy (NRT)	Motivational interviewing counselling, provision of fruit and vegetables, a cookbook and educational videos (see Ahluwalia, diet, above)	Biochemically confirmed smoking abstinence 7 days	6 month assessment
Andrews[56] Supplemented by Andrews et al.	RCT	▪ 103 African American women from a subsidised housing development.	Counselling, NRT and community health worker	Smoking print materials, group education on	Biochemically confirmed smoking abstinence 7 days	6 month assessment

(2005)[57] 2007 USA		▪ Mean age = 40.2 (11.8), 18-85 ▪ Mean household income $689/month, range $0 to $2,300 /month	sessions	other topics		
Bullock[58] **2 arms** 2009 USA	RCT	▪ 695 women attending Women Infant and Children Nutritional Supplement (WIC) clinic ▪ Mean age = 22 (4.6) ▪ Income not reported but all women were eligible for WIC program so have household monthly gross income of ≤185% of the federal poverty level (see also Chang participant description)	**Social Support (SS) intervention:** Telephone calls from a nurse and 24 access through a pager **Social Support plus booklets (SS+B) intervention:** Same with eight mailed booklets on stopping smoking in pregnancy	**Booklets alone (B) control intervention:** Eight mailed booklets on stopping smoking in pregnancy **Control (C) intervention:** no intervention	Biochemically confirmed smoking abstinence last 7 days	End of pregnancy (T2) Post-delivery follow up (T3)
Dornelas[59] 2006 USA	RCT	▪ 105 pregnant smokers from a non-profit tertiary care community hospital ▪ Mean age = 26.1(5.8), 18-42 ▪ 49% household income of ≤$15,000/year.	Counselling session and telephone follow-up	Usual care: standard smoking cessation advice	Biochemically confirmed smoking abstinence for previous 7 days	End of pregnancy assessment Six months post-partum follow-

						up
Fang[60] 2006 USA	RCT	▪ 66 low-income Chinese and Korean smokers ▪ 63 m, 3 f ▪ Mean age ranged from 43.97 (17.21) to 48.35 (16.47) ▪ 68% had individual income ≤$15,000/year	Motivational interviewing style session + NRT	General health counselling, an educational booklet +NRT	SR smoking abstinence, last 7 days	1 week assessment 1 month and 3 month follow-up
Froelicher[61] 2010 USA	cRCT	▪ 60 African Americans from a low-income neighbourhood with high health disparities ▪ 17 m, 43 f ▪ Mean age = 46 (10.8) ▪ 55.9-61.5% individual income <$15,000/year	Smoking cessation program and tobacco industry and media messages hand-outs	Standard smoking cessation program and written hand-outs	Biochemically confirmed abstinence	6 month assessment 12 months follow-up
Gordon[62] 2010 USA	cRCT	▪ 2549 smokers visiting public dental clinics serving people of low-income ▪ 1241 m, 1508 f ▪ Mean age = 40.5 (12.6) ▪ Income not reported but participants at or below 200% of the federal poverty threshold as	Brief smoking advice	Usual care	SR smoking abstinence for last 6 months	7.5 months end point

		defined by the US Census Bureau 2006-8. This equates to an individual income ≤$19,600 /year*				
Liles[63] 2009 USA	RCT	▪ 150 low-income mothers who smoke from WIC programme ▪ Mean age 30.1 (7.1) ▪ Income not reported but all eligible for WIC program so have household monthly gross income of ≤185% of the federal poverty level (see also Chang participant description)	Counselling to decrease second-hand smoke exposure	Not specified	Biochemically confirmed quit for at least 7 days over study period	18 month assessment
Miller[64] 2009 Australia	RCT	▪ 1377 disadvantaged smokers ▪ Age not specified ▪ Income not reported but all participants were eligible for an Australian Government concession card, which currently requires an individual income of <$2,072AUS/month ($1948 US dollars)**	Availability of a quitline and NRT	Availability of a quitline without NRT	SR smoking abstinence: previous day	3 month assessment 6 months and 12 months follow-up
Okuyemi[65]	RCT	▪ 430 homeless adult smokers	Multi session	Standard care of	Biochemically	8 weeks (post-

2013 USA		▪ Mean age 44.4 (9.9) ▪ 63.5% had a monthly family income <$400	motivational interviewing intervention and NRT	one short counselling session and NRT	confirmed smoking abstinence: previous seven days	intervention) 26 weeks (follow-up)
Reitzel[66] 2010 USA	RCT	▪ 251 low-income pregnant ex-smokers ▪ Mean age 24.6 (5.3) ▪ 55% household income <$30,000/year	Motivation and problem solving intervention	Usual care: self-help materials and guideline-based relapse prevention advice	Biochemically confirmed smoking abstinence following delivery of baby	Follow-up week 26 post-partum
Solomon[67] 2000 USA	RCT	▪ 214 medicaid-eligible female smokers of childbearing age ▪ Mean age 33 (8.5) ▪ Mean individual income $12,802 /year	3 months of telephone support and NRT	NRT only	Biochemically confirmed smoking abstinence: previous seven days	3 months 6 months follow-up
Solomon[68] 2005 USA	RCT	▪ 330 low-income women smokers ▪ Mean age ranged from 33.7 (8.9) to 34.8 (8.2) ▪ Income not reported, but all receiving Medicaid (see Jackson description) or Vermont Health Assistance Plan for low-income Vermonters (not further	3 months of telephone support for psychosocial issues surrounding quitting and NRT	NRT only	SR smoking abstinence, last 7 days or 30 days	3 months 6 months follow-up

		specified)				
Sykes[69] 2001 UK	RCT	▪ 260 adult smokers from a deprived area ▪ 94 m, 166 f ▪ Age not specified ▪ Income not reported, 42% in manual occupation or unemployed and therefore defined as 'low-income'	Quit for life self-help cognitive behavioural programme	Usual care 'stopping smoking made easier' booklet	Biochemically confirmed smoking abstinence: previous seven days	Follow-up outcome point
Volpp[70] 2006 USA	RCT	▪ 179 low-income veteran smokers ▪ 168 m, 10 f ▪ Mean age ranged from 52.7 to 53.1 ▪ 49.7% household income <$15,000 /year	Free smoking cessation program +financial incentives for attending class and quitting smoking	The same program without incentives	Biochemically confirmed smoking abstinence: previous seven days	30 day assessment 6 months follow-up
Wu[71] 2009 USA	RCT	▪ 139 low-income Chinese American smokers ▪ 107 m, 15 f ▪ Mean age ranged from 43.9 (12.1) – 45 (12.8) ▪ 72%-77% individual income <$20,000 /year	Motivational interviewing counselling for smoking	General health counselling	Biochemically confirmed quit at follow-up	6 month assessment

Note. RCT=randomised controlled trial. cRCT= cluster randomised controlled trial. SR=self-reported. If a study had multiple arms testing interventions for one behaviour, they are listed under one section in the table. If the study included interventions with the same participants for more than one behaviour, the characteristics for each

intervention are reported separately for the relevant behavioural target *Source: http://familiesusa.org/product/federal-poverty-guidelines retrieved 14.06.14 ** Source: http://www.humanservices.gov.au/customer/enablers/centrelink/low-income-health-care-card/income-test, retrieved 14.06.14

Table 2: Risk of bias for individual studies, in alphabetical order (following Avenell et al. 2004).[27]

	Lead study author	Quality of random allocation concealment	Description of withdrawals and drop outs	Intention to treat analysis?	Participants blinded to treatment status?	Intervention facilitators blinded to treatment status?	Outcome assessors blinded to treatment status?
1	**Ahluwalia**[31,32]	A	Numbers and reasons	Yes	Bi	C	C
2	**Andrews**[56,57]	C	Numbers stated only	Yes	Bi	Bi	Bi
3	**Armitage**[25]	C	Numbers stated only	Yes	Ai	Ai	C
4	**Auslander**[33]	C	Numbers stated only	No	Bi	Bi	Bi
5	**Bullock**[58]	Bi	Numbers and reasons	Yes	Ai	C	Ai
6	**Chang**[34,35]	Bi	Numbers and reasons	No	Aii	Aii	Bi
7	**Dangour**[48,49]	Bi	No numbers given	Yes	C	C	Ai
8	**Dornelas**[59]	Bi	Numbers and reasons	Yes	Bi	Bi	Bi
9	**Dutton**[50]	Bi	Numbers and reasons	Not clear	C	C	C
10	**Elder**[36]	Bi	Numbers and reasons	No	C	Bi	Bi
11	**Emmons**[37]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
12	**Fang**[60]	C	Not mentioned	Yes	C	C	C
13	**Froelicher**[61]	Bi	Numbers stated only	Yes	C	C	Bii
14	**Gans**[38]	A	Numbers and reasons	Yes	Bi	Bi	Aii
15	**Gordon**[62]	Bi	Numbers stated only	No	Bi	Bi	Bi
16	**Jackson**[39]	A	Numbers and reasons	Yes	C	Ai	C
17	**Keyserling**[40,41]	A	Numbers and reasons	Yes	Bi	Bi	Bi
18	**Liles**[63]	Bi	Numbers stated only	Yes	Bi	Bi	Ai
19	**Marcus**[51]	Bi	Numbers and reasons	Yes	Bi	Bi	Aii

20	**Miller**[64]	Bi	Numbers stated only	Yes	C	Bi	C
21	**Nitzke**[42,43]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
22	**Okuyemi**[65]	Bi	Numbers and reasons	Yes	C	Bi	Bi
23	**Olvera**[52,53]	Bi	Numbers and reasons	No	Bi	Bi	Bi
24	**Parra-Medina**[44]	Bi	Numbers stated only	No	C	Aii	Aii
25	**Pekmezi**[54]	Bi	Numbers and reasons	Yes	Bi	Bi	Bi
26	**Reitzel**[66]	Bi	Numbers stated only	Yes	C	C	C
27	**Sanchez-Johnsen**[45]	Bi	NA	NA	Bi	Bi	Bi
28	**Steptoe**[46]	C	Numbers stated only	Yes	Ai	C	C
29	**Tessaro**[47]	C	Numbers stated only	No	Bi	Bi	Bi
30	**Solomon**[67]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
31	**Solomon**[68]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
32	**Sykes**[69]	Bii	Numbers stated only	No	Ai	Ai	Bi
33	**Volpp**[70]	A	Numbers stated only	Yes	C	Ai	C
34	**Whitehead**[55]	Bi	Numbers stated only	Yes	Bi	Bi	Bi
35	**Wu**[71]	Bi	Numbers and reasons	No	C	C	C

Note. *NA=not applicable*

Quality of random allocation concealment:
A = good attempt at concealment
Bi = states random allocation but no description given
Bii= attempt at concealment but real chance of disclosure of assignment prior to formal trial entry
C = definitely not concealed

Blinding:

Ai = action taken at blinding likely to be effective
Aii = blinding stated but no description given
Bi = no mention of blinding
Bii = attempt at blinding but reason to think it may not have been successful
C = not blinded

Table 3: Intervention outcomes: organised by behavioural target and then by alphabetical order of lead study author

Study reference and follow-up point	Outcome measure	Control group baseline mean n (SD/SE)	Intervention group baseline mean (SD/SE)	Control group endpoint mean (SD/SE) or proportion abstinent from smoking	Intervention group endpoint mean (SD/SE) or proportion abstinent from smoking	Follow-up outcome mean (SD/SE) or proportion abstinent from smoking	Intervention effect as reported in the paper
DIET							
Ahluwalia[31,32] (diet) 6 month	SR Portions of fruit and vegetables per day, last 7 days	2.17 (1.63)	2.06 (1.73)	2.44 (2.42)	3.10 (2.48)		▪ Mixed linear model found significant difference between groups (p=.04)
Auslander[33] (diet) Post test: 3 month post baseline	SR mean % of calories from fat	36%	35.9%	35.6%	32.1%	6 month follow-up **C** 34.5% **IV** 32.3%	▪ ANCOVA test and post-hoc tests revealed significant difference between intervention and control group at 3 month post test [t=-4.01 p<.01] and 6 month follow-up –[2.50 p<.05]
Chang[34,35] (diet) 2 months	SR cups of fruit and vegetables per day	4.25 (2.91)	4.87 (4.41)	4.73 (3.41)	6.33 (3.42)	8 month follow-up **C** 5.56 (3.50) **IV** 3.87 (3.52)	▪ General linear mixed model found no significant intervention effect at either time point p>.05

Elder[36] **(2 arms)** M2 time point 12 weeks	SR Mean grams of fat per day	56.8 (SD25.2)	**Tailored IV group** 59 (SD28.6) **Promotora IV group** 60.2 (SD26.6)	49.1 (SE1.9)	**Tailored IV group** 49.8 (SE2) **Promotora IV group** 43.1 (SE1.9)	M3 time point 6 months post-intervention' **C** 48.2 (SE2.0) **tailored IV** 50(SE2) **promotora IV** 46.4 (SE2) M4 timepoint '12 months post-intervention' **C**51.9 (SE2.3) **tailored IV** 45.3 (SE2.4) **promotora IV** 50.4 (SE2.3)	▪ Significant differences between groups reported at M2 [$F(2.309)$=3.73, p=0.025] Group differences were not maintained at M3 or M4 (not further specified).
Emmons[37] (diet) Endpoint	SR Fruit and veg servings per day	3.19 (SE0.062)	3.28 (SE0.062)	3.13 (SE0.064)	3.57 (SE 0.064)	-	▪ Significantly greater changes in **IV** group than **C** group p=.005
Gans[38] **(3 arms)**	SR Fruit and veg servings per day	NS	NS	Change from baseline 0.42 (2.51)	Change from baseline	7 months **C** 0.24 (2.52),	▪ At 4 months significant differences between **C** and **ST**

4 months					**MT IV group** 0.72 (2.55) **MTI IV group** 0.36 (2.58) **ST IV group** 0.92 (2.92)	**MTIV** 0.68 (2.63), **MTI IV** 0.49 (2.58) **ST** 0.58 (2.69)	(*p*=.01), **ST** and **MTI** (*p*=.01), **MT** and **MTI** (*p*=.01), **C** and **MT** (*p*=.05) ▪ At 7 month follow-up, only significant differences between **C** and **MT** (*p*=.02)
Jackson[39] (diet) 4 weeks	SR fruit and vegetable intake per day	3.3 (1.7)	3.0 (1.6)	3.1 (1.5) change of -0.2 (1.5)	3.44 (1.6) change of +0.44 (1.6)	-	▪ T test showed significant difference between groups p<.001
Keyserling[40,41] (diet) 6 month assessment	End point data: objectively measured fruit and veg intake, via median serum carotenoids (ug/dL) Follow-up data: fruit and vegetable consumption via Dietary Risk Assessment (score range 0-103,	3.8(SE0.05)	3.8(0.06)	3.9 (SE0.03)	4.0 (SE0.03)	12 month assessment: **C** 32.8(SE0.7) **IV** 29.2 (SE0.7)	▪ Marginally significant difference between adjusted mean objective measures at 6 month assessment (*p*=.05) ▪ Significant difference at follow-up12 month assessment for Dietary Risk Scores (*p*<.001)

	lower=healthier)						
Nitzke[42,43] 12 month assessment	Daily fruit and vegetable intake, servings	4.72(2.61)	4.75 (2.86)	4.60 (2.45)	4.90 (2.35)	-	▪ Significant intervention effect from ANOVA [*F*=3.49, p<.05]
Parra-Medina[44] 12 month assessment	Dietary risk assessment score (rated between 0 and 104, where lower scores equal a lower intake of saturated fat and cholesterol)	32.1 (8.5)	32.0 (9.1)	26.8 (7.3)	21.3 (6.9)		▪ Mean reductions in dietary risk assessment score were significantly greater amongst intervention participants (*p*<.001)
Sanchez-Johnsen[45] (diet) 6 week assessment	SR fruit and veg servings per day	6.11(3.11)	5.66 (3.80)	4.63 (2.51)	5.33 (3.40)	-	▪ ANOVA test suggested significant intervention effect [*F*=4.716, *p*=.04]
Steptoe[46] 12 months	SR fruit and veg servings per day	3.67 (2.0)	3.6 (1.81)	0.87 (2.22)	1.49 (2.2)	-	▪ Significant difference in change =0.62 servings, [*p*=.021, 95% CI 0.09 to 1.13)]
Tessaro[47]	SR fruit and veg	3.87 (1.90)	3.90 (1.89)	3.55 (2.24)	3.74 (2.11)		▪ Paired *t* test indicated no

3 months	servings per day						▪ significant difference between 3 month follow-up scores (p=.32)
PHYSICAL ACTIVITY							
Armitage[25] 1 month	SR metabolic equivalent minutes exercise per week (MET mins)	896.89 (1657.94)	733.12 (945.15)	868.33 (1659.01)	1080.62 (1317.70)	-	▪ Significant intervention effect according to ANCOVA analysis [F(1,66)=7.28, p=.009]
Chang[34,35] (Physical activity) 2 months	SR metabolic equivalent minutes exercise per week (MET mins)	27.28 (29.85)	29.76 (26.74)	33.51 (29.34)	41.09 (29.87)	8 month follow-up **C** 36.02 (29.3) **IV** 53.20 (30.24)	▪ General linear mixed model, no significant effect at 2 months (effect size d=0.25, CI -0.24 to 0.74) or at 8 months (effect size d=0.57, CI -0.04 to 1.18)
Dangour[48,49] 24 month assessment	Objectively measured walking capacity: metres walked in six minutes	452.8 (78.4)	447.9 (72.4)	432.8 (77.8)	466.5 (86.7)		▪ Significant difference between groups (p=.001)
Dutton[50] Post-treatment	SR hours exercise per week	NS	NS	Mean change from baseline: 0.59(10.99)	Mean change from baseline: 0.75 (7.58)		▪ ANOVA test found no significant difference between conditions (p=.65)

Emmons[37] (physical activity) Follow-up	SR Mean hours per week	4.93 (SE0.16)	4.8 (SE0.16)	4.91 (SE0.16)	4.77 (0.17).		▪ No significant differences between groups at follow-up [*p*=.51]
Jackson[39] (Physical activity) 4 weeks	SR minutes per week of physical activity	122 (SD not reported)	127 (SD not reported)	136 (135) [change of 14]	155 (145) [change of 28]		▪ Means not significantly different at 4 week follow-up according to an unpaired Student's *t*-test *p*=.42
Keyserling[40,41] (Physical activity) 6 month assessment	Objectively measured PA; accelerometer moderate minutes per day	13(SE1.2)	11.6 (SE1.3)	11.7(SE1.1)	12.2(SE1.1)	12 month follow-up **C**12.5(SE1.1), **IV** 11.0(SE1.1)	▪ Not significantly different according to ANCOVA, at 6 months [*p*=.74] or 12 month follow-up [*p*=.33]
Marcus[51] 6 months post-intervention follow-up	SR moderate to vigorous minutes of physical activity per week	3.02 (10.3)	1.87 (6.86)	32.98 (82.82)	73.36 (89.73)		▪ Intervention group significantly more active than control group at 6 months, according to a longitudinal regression controlling for baseline differences (*p*<.001)
Olvera[52,53] 12 week assessment	SR activity level on a scale from 0 (sedentary) to 7 (vigorous)	1.2 (1.5)	1.4 (0.9)	1.2 (0.9)	2.1 (1.6)		▪ No significant effect according to ANCOVA [*F* 1.35, *p*=2.57, *d*=.4]
Pekmezi[54]	SR minutes of	11.88	16.56	96.79 (118.49)	147.27 (241.55)		▪ No significant between group

6 months	physical activity per week	(21.99)	(25.76)				differences according to ANOVA [$F(1,91)=1.37$, $p=.25$]
Sanchez-Johnsen[45] (Physical activity) 6 week assessment	SR times engaged in activity designed to improve fitness on a scale from 1 (0 times) to 9 (more than 7 times)	2.11 (2.18)	2.11 (1.75)	2.98 (2.48)	3.66 (1.78)		▪ No significant difference according to ANCOVA [$F=0.634$, $p=.434$]
Whitehead[55] 1 month assessment	SR time spent in physical activities for last 7 days, yielding an estimated caloric expenditure	2507.82 (SE 2.64)	2507.35 (2.55 SE)	2506.72 (2.65)	2511.76 (2.56)	6 month assessment **C** 2507.67 (2.98) **IV** 2511.2 (2.89)	▪ A doubly multivariate ANOVA with planned comparisons showed significant differential group changes at 1 month [$F(1,205)=17.98$, $p<.001$] and 6 months [$F(1,205)=4.07$, $p<.05$]
SMOKING							
Ahluwalia[31,32] (Smoking) 6 month	Biochemically confirmed smoking	All smoked at baseline	All smoked at baseline	9 of 93 abstinent	4 of 57 abstinent	-	▪ Adjusted Mantel-Haenszel chi-square statistic revealed no significant difference between

assessment	abstinence 7 days						groups (p=.73).
Andrews[56,57] 6 month assessment	Biochemically confirmed smoking abstinence 7 days			3 of 52 abstinent	14 of 51 abstinent	-	▪ Odds ratio 4.9, CI -1.51 to 15.89 ▪ Main effect of intervention group variable in multiple regression, p=.001.
Bullock[58] **2 arms** End of pregnancy (T2)	Biochemically confirmed smoking abstinence last 7 days			**B control group** 27 of 141 **C control group** 22 of 128	**SS+B IV group** 22 of 129 **SS IV group** 29 of 132	Post-delivery follow up (T3) **B control group** 19 if 141 **C control group** 17 of 128 **SS+B IV group** 16 of 129 **SS IV group** 15 of 132	▪ Likelihood ratio chi-square not significantly different X^2=1.33, p=.72 at T2 end of pregnancy X^2=1.39, p=.71 at T3 post-delivery follow-up
Dornelas[59] End of pregnancy assessment	Biochemically confirmed smoking abstinence for previous 7 days	-	-	5 of 52	15 of 53	Six months post-partum **C**2 of 52 **IV** 5 of 53	▪ Significant difference at end of pregnancy assessment only, according to chi-squared test X^2=5.94(1), p=.015.
Fang[60] 1 week	SR smoking abstinence, last 7	-	-	8 of 32	15 of 34	1 month **C**10 of 32, **IV**	Intervention and Controls not significantly different at 1

assessment	days					19 of 34 3 months **C**9 of 32, **IV** 16 of 34	week follow-up according to chi-square test $X^2(1)=2.51$, $p=.11$. Significant differences at 1 month [$X^2(1)=4.06$, $p<0.05$] but not at 3 months [$\chi^2(1)=2.51$, $p=0.11$]
Froelicher[61] 6 month assessment	Biochemically confirmed abstinence	-	-	3 of 26	3 of 22	12 months **C**1 of 19, **IV** 3 of 19	▪ Not significantly different – not further specified.
Gordon[62] 7.5 months end point	SR smoking abstinence for last 6 months	-	-	8 of 439	28 of 530	-	▪ Significant between groups effect [$F(1,12)=14.62$, $p<.01$].
Liles[63] 18 month assessment	Biochemically confirmed quit for at least 7 days over study period	-	-	5 of 74	15 of 76	-	▪ Fisher's exact test: difference statistically significant $p=.029$
Miller[64] 3 month assessment	SR smoking abstinence: previous day	-	-	97 of 377	397 of 1000	6 months **C**80 of 377, **IV** 309 of 1000 12 months **C**83 of 377 **IV** 191 of 1000	▪ Chi squared test: significant difference reported at 3 and 6 month assessment [$p\leq.001$] but not at 12 months [p value not specified]
Okuyemi[65]	Biochemically	-	-	19 of 214	20 of 216	26 weeks	▪ No significant group

8 weeks (post-intervention)	confirmed smoking abstinence: previous seven days					(follow-up) **C** 12 of 214 **IV** 20 of 216	difference according to chi squared test at week 8 (p=0.89) or week 26 (p=0.15)
Reitzel[66] Follow-up week 26 post-partum	Biochemically confirmed smoking abstinence following delivery of baby	None smoked at baseline (relapse prevention intervention)	None smoked at baseline (relapse prevention intervention)	19 of 115	31 of 136		▪ Main effect of treatment approached significance according to a continuation ratio logit model [$X^2(1)=3.10$, p=.08]
Solomon 2000[67] 3 months	Biochemically confirmed smoking abstinence: previous seven days	-	-	30 of 108	44 of 106	6 months **C**20 of 108 **IV** 24 of 106	• Experimental condition strongest predictor in logistic regression at 3 months: OR 2, CI 1.09 TO 3.68. Not a significant predictor at 6 month follow-up (not further specified)
Solomon 2005[68] 3 months	SR smoking abstinence, last 7 days	-	-	58 of 159	82 of 171	6 months **C** 48 of 159 **IV** 65 of 171	• Significant difference at 3 months [p=.035] according to Chi square test but not at 6 month follow-up [p value not

							specified]
Sykes[69] Follow-up	Biochemically confirmed smoking abstinence: previous seven days	-	-	6 of 107	21 of 122		• Significant difference compared to controls [$X^2(2)=22.339$, $p<.001$]
Volpp[70] 30 day assessment	Biochemically confirmed smoking abstinence: previous seven days	-	-	4 of 87	15 of 92	6 months **C** 4 of 87 **IV** 6 of 92	▪ Significant difference at 30 day assessment according to Chi squared test [$X^2=6.46$, $p=.01$], but not at 6 month assessment [$X^2 = 0.31$, $p=0.57$]
Wu[71] 6 month assessment	Biochemically confirmed quit at follow-up	-	-	20 of 62	40 of 60	-	▪ Significant difference according to logistic regression, OR 4.32, CI: 2.01 to 9.27, $p<.001$

Note. SR=self-reported NS=not specified, **C**=control group **IV**= intervention group SE=standard error, OR=odds ratio, CI=confidence interval. $p<.05$ was considered statistically significant. Unless otherwise specified, in smoking interventions no participants were abstinent from smoking at baseline

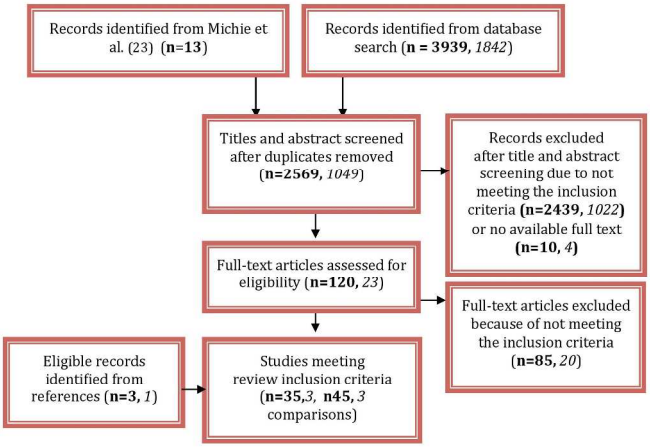


Figure 1: Study selection flow diagram (italics signify numbers from July 2014 updated search)
254x190mm (300 x 300 DPI)

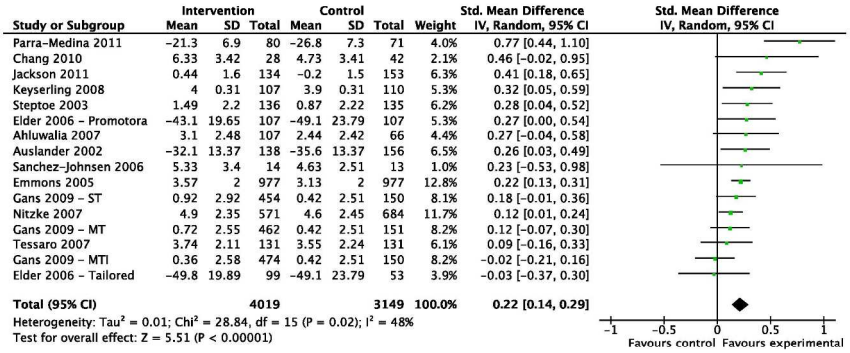


Figure 2: Standardised Mean Differences immediately post intervention for studies focusing on dietary change (ordered by effect size)
209x279mm (300 x 300 DPI)

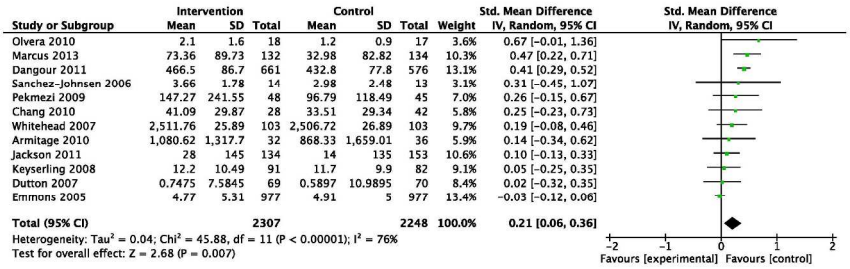


Figure 3: Standardised Mean Differences immediately post intervention for studies focusing on physical activity change, (ordered by effect size)
209x279mm (300 x 300 DPI)

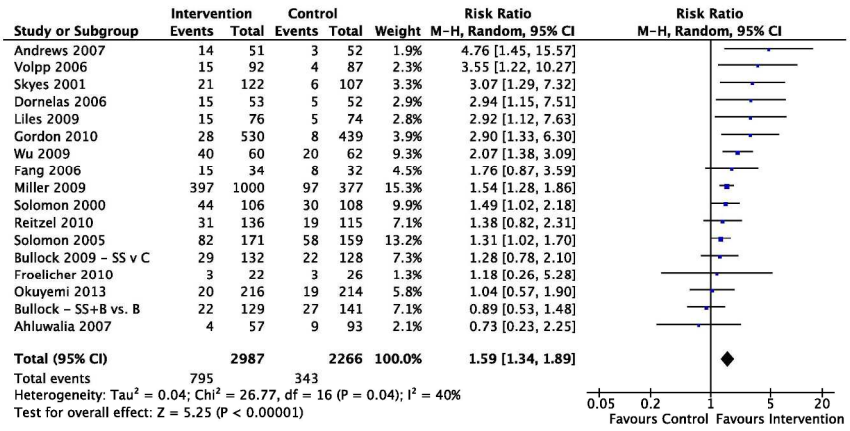


Figure 4: Relative Risk of smoking abstinence immediately post intervention for studies focusing on smoking interventions (ordered by effect size)
209x279mm (300 x 300 DPI)

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5-6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7-8
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supplementary file 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	9
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	9-10
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	9-10

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	10
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	10
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-11 (&Table 1)
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	13
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	13-14 (and table 3)
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	13-14
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	14
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	13-14
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	15-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	16-17
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	17
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	20

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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